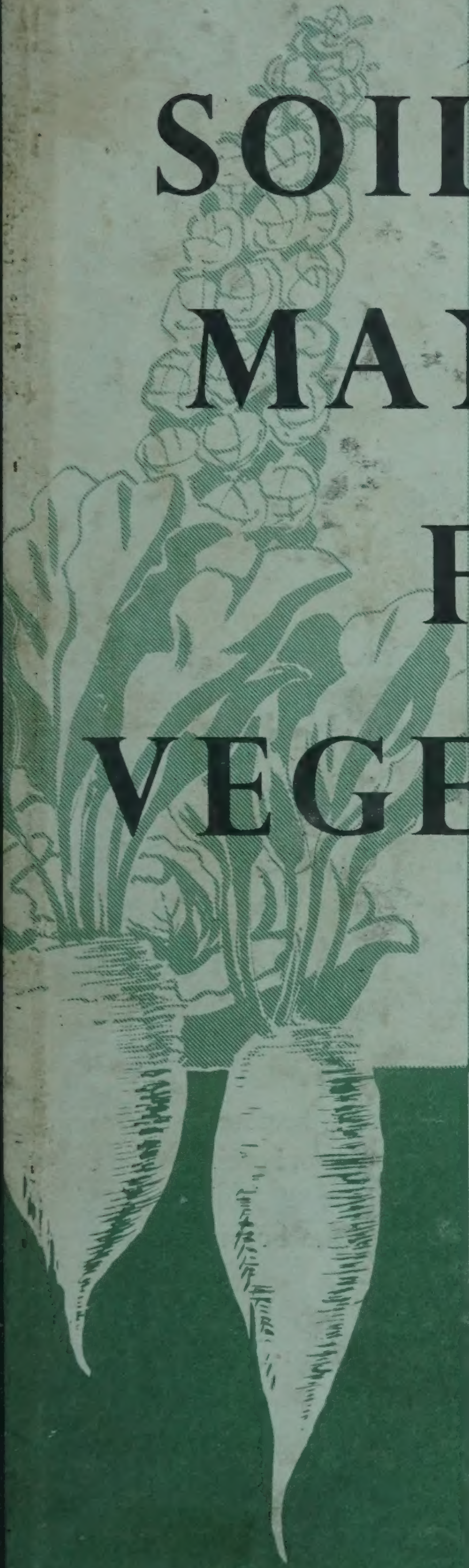

SOILS AND MANURES FOR VEGETABLES

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Foreword

It is now twenty years since the previous edition of this bulletin appeared, and it has been out of print for a long time. In 1942 Growmore Bulletin No. 6: *The Manuring of Commercial Vegetable Crops* was issued to provide advice at a time of expansion of vegetable production coupled with war-time problems of fertilizer supply. It has continued to fill the gap, but the time has now come to take fuller account of advances in scientific knowledge and changes in practice with the passage of years.

The bulletin has been completely rewritten and is in effect a new publication. The information on soils has been expanded and soils for vegetables are now given a chapter to themselves. The fundamental work on mineral nutrients and deficiencies is fully dealt with for the first time, and practical recommendations made concerning major and micro-nutrient deficiencies. The problems arising from scarcity of animal manures and the high cost of concentrated organic manures are considered from a practical standpoint.

Recommendations concerning the practical manuring of different vegetables continue to be handicapped by the dearth of experimental evidence, but there is good reason to believe that this will gradually be rectified in the future. Meantime the current practice of vegetable growers is considered in the light of experience of the scientific and horticultural advisers in the vegetable growing areas. A final chapter on the manuring of gardens and allotments brings out the main points of importance to the private gardener.

The Soil Chemists' Publications Committee under the chairmanship of Mr. J. B. E. Patterson, with the assistance of members of the Vegetable Group of the National Agricultural Advisory Service, is responsible for the new edition. The Committee is specially indebted to the members of the working party, Mr. W. Dermott, Mr. J. B. E. Patterson, Dr. N. H. Pizer, Mr. J. Rhodes and the technical editor Mr. R. T. Pearl, for undertaking the work of preparing the final text.

Ministry of Agriculture, Fisheries and Food

October, 1959

Contents

Introduction

IN the past twenty years or so, the vegetable grower has been well served by fundamental research on the mineral nutrition of crops, and the effect of deficiencies of major and micro-nutrients. The progress that has been made is brought out by the fact that in the previous edition of this bulletin (in 1938) nitrogen, phosphorus and potassium were the only nutrients mentioned as being of importance in manurial dressings for maximum production. Now a number of other nutrients have been found to be important in the manuring of vegetable crops, including some micro-nutrients. Long Ashton Research Station has played a leading part in this work.

On such practical matters as what manures and fertilizers to use and what quantities to apply in order to obtain favourable yields and good quality produce, there has been much less progress, and there is still a lack of reliable information from manurial experiments on which to base practical recommendations.

Nevertheless, since the war of 1939–45, there have been major developments in relation to vegetable research which hold out great promise for the future. In 1949 the National Vegetable Research Station was established at Wellesbourne, Warwickshire, to investigate the problems of vegetable production in this country. About the same time, the organization of a chain of experimental horticulture stations to cover the country was started in conjunction with the National Agricultural Advisory Service. These stations are undertaking field experimental work under a wide range of soil and climatic conditions and are working in close liaison with the national research stations.

Much of the early soil survey work in this country grew out of advisory work, and has included both general work on relating soils to crop performance, particularly by the advisory soil chemists at regional centres, and also special soil surveys mainly in important fruit-growing areas by small teams of advisers and research workers.

In this connection the right choice of soil for various land uses has been placed on a sounder scientific basis by the adoption of an international system of soil classification with its accompanying techniques of field examination by soil profile and texture.

In 1947 the Soil Survey of Great Britain was established to combine and develop the earlier soil survey work on a national scale. This body will be concerned with surveying and mapping systematically the soil types and their distribution, but it will be a very long time before comprehensive soil maps can be obtainable for most of the country.

Although there have been no specific surveys of soils for vegetable growing, valuable experience in the use of soil survey techniques has been gained from the various soil studies referred to above, and the results have been applied to the examination of soils for vegetable growing, particularly by the soil advisory chemists of the National Agricultural Advisory Service. As a result soil assessment for vegetable production, as for other crops, has been placed on a sounder footing, and it has been possible to include the results of this experience in a new section on Soils for Vegetables.

Summing up the present situation, it is reasonable to expect that the industry will benefit in future from an increasing fund of information on the practical manuring of vegetable crops in all its aspects, which will flow from the programme of work at the national research and experimental stations, and the field work of the regional and local advisers of the National Agricultural Advisory Service.

Soils for Vegetables

BEFORE the advent of motor transport in the 1920s, market gardening was more or less confined either to areas near to large centres of population or to areas further afield where there were good rail transport facilities nearby. Today, the close network of road and rail has enabled market gardening to extend to many areas remote from large markets and industrial population, with the result that it is now carried on under a much greater variety of soil and climatic conditions. Although vegetable crops can be grown on some of the heavier soils, the more intensive work is still practised on the lighter ones.

In the days of horse transport an adequate supply of stable manure was obtainable from the big towns. The very heavy dressings applied made it possible to maintain a high fertility status and to improve the texture, structure and water-holding capacity of the light market garden soils of the country. Today this source of bulky organic manure has practically disappeared and the grower has to use other methods of keeping up the general fertility of his land (see pages 14–21 and 53–55).

SOIL SUITABILITY

All classes of soil are used to some extent for vegetable production and, while no class can be said to be the best, some are more generally suitable than others. The soil classes generally preferred are sands, sandy loams, silts and peat soils, but clay loams with proper management can be made to produce useful crops of some vegetables.

Although differences in soil texture (e.g., sandy loams, silts, clay loams) will be used here as a convenient basis for classifying soils, it is only one of the factors for assessing the usefulness of soils for vegetable growing. Other important factors include, for example, depth of top soil, the sharpness of transition between top soil and subsoil, the presence or absence of a pan, and conditions of natural drainage. Favourable features for crop growth include a deep top soil, a gradual transition between top soil and subsoil, and free but not excessive drainage. Nutritional status and lime requirement are also important, but often these can be put right by suitable treatment more easily than other factors.

Soil Properties

The properties needed in soils for vegetable growing are ease of working, good aeration, ability to take up water readily and to dispose of any surplus, a sufficiently stable tilth or structure, and pore distribution such as to combine good retention with ready availability of water to crops.

Ease of working is especially a property of the sandy soils and peats. Aeration depends on pore size and adequate drainage; large pores are a feature of sandy soils and account for their good aeration, but the aeration of heavier soils is to a large extent dependent on their ability to absorb and dispose of water, in which a number of factors play a part. Good drainage and favourable water retention depend on good soil structure and stability as well as adequate porosity. Stability of the soil to rainfall or irrigation depends on how much clay and organic matter there is in it, since these are the chief binding agents. Conversely, a high proportion of fine sand or silt leads to lack of stability.

A ground water-table is a valuable asset if it is in the right place, neither so near the surface that the pore spaces above become filled by rain, nor so deep that the roots of young plants cannot benefit from it (see page 6 for details of suitable depths).

Desirable soil properties are seldom all present in any one soil. Thus, sandy soils have low water retention even when improved by organic matter. Silty and very fine sandy soils lack stability, especially when organic matter is low, or after prolonged and intensive arable use; the soil runs, the pores silt up and the surface tends to cap after rain. Clay loams become wet and sticky and are difficult to cultivate, particularly in periods of prolonged wetness, as for example in winter and early spring. Peat soils may lack binding qualities and tend to blow unless they are improved by claying.

Inherent soil defects may limit the range of crops and the season of working and cropping the land. Thus clay loams tend to be "one-crop land", whereas sandy loams are potentially intensive crop land. On some soils vegetable production may be confined to a few crops only, e.g., on clay loams brassicas and maincrop peas and beans may be mainly grown, while on the light fen peats and dry sandy soils in some areas carrots may be almost the only vegetable.

Situation and still more climate are determining factors in cropping. For example, sandy soils are most useful in a wet climate or where they can be irrigated, or where a water-table is near the surface, whereas clay loams are most manageable under conditions of low or moderate rainfall and in higher-lying situations where drainage through the soil or off the surface is better. On the whole it is on the medium sandy loams that the greatest diversity and intensity of cropping can be practised.

SOIL EXAMINATION AND ASSESSMENT

In examining a soil for its suitability for vegetable production, points to bear in mind include soil texture, soil structure, the uniformity of the soil profile, soil colour, conditions and depth of natural drainage (including water-table, if any), the depth of top soil, the presence or absence of a pan, soil organic matter, nutrient status including pH. Such matters as the topography and exposure of the site are also important and should be considered in relation to other factors. Most of the soil examination can be made directly in the field and very largely by simple soil boring by means of an auger, from the surface down to a depth of 3–4 ft. The soil auger withdraws a 6 in. section of the soil at a time, and successive cores are examined by feel and eye; in this way a picture can be built up of the soil profile (the soil as seen in vertical section),

its depth, drainage conditions and much more besides. Soil samples can be taken by the same means at any desired depth for subsequent soil analysis (for nutrient status and pH determination).

Auger borings provide information on soil consolidation and to some extent on soil structure, but the latter can best be examined properly by digging small pits and studying the soil layer by layer. The work is slower and laborious in comparison with augering, but it is usually very rewarding and need only be done in areas where auger borings have indicated adverse conditions in the soil.

Soil Texture

The texture of a soil is decided by its clay, silt and sand fractions and its organic matter content.

The practical method of assessing these qualities is quite simple — by the feel of the moist soil when examined by rubbing a small sample between the thumb and forefinger. Sand can be detected by the sensation of roughness or grittiness — the finer the sand the less the grittiness. Silt has a smooth silky feel, as also has organic matter, but these are readily distinguished from each other by soil colour and other characteristics. Clay may feel smooth, but the surface of the soil becomes polished when rubbed out between the fingers; clay is plastic and tends to mould in the piece instead of crumbling; it becomes sticky when wet. As experience is gained, it soon becomes easy to distinguish predominantly sandy, silty or clayey soils, and in time to assess more accurately different proportions of these constituents as judged by the textural differences experienced.

Silt, very fine sand and fine sand, when present in large amounts in soils, may impart heaviness and imperviousness to water such as is more commonly associated with clays. This arises through the particles packing close together and a strong tendency for them to flow on being wetted. A tilth created on such a soil is unstable, and under heavy rainfall or irrigation may set hard and cap on the surface, and thus interfere with aeration and drainage.

Clay imparts stability to soil structures, good or bad. Clay tilths will stand up to rain or watering when wet or dry, and to much mechanical treatment when on the dry side. Stoniness of the soil, if excessive, produces its own special difficulties and is particularly a nuisance where accurate row-crop machine work is needed.

Soil Structure

Good soil structures are porous and fairly stable to water. They are produced by suitable cultivation, vigorous root activity, alternate wetting and drying, and freezing and thawing. When found they are evidence of a good rooting medium containing suitable amounts of clay and organic matter. Good crumb structures are probably the best for crops but they are not possible in all soils. Tilths that have been forced from harsh clods or formed from naturally hard granules are poor for root range, moisture supply and availability of nutrients. Tilths that are unstable to water may often be detected by the fact that they break down rapidly when an air-dry fragment of the soil is dropped into water; when very unstable this can also happen with slow wetting.

Soil structures change from the surface downwards. In good soils they

are open and porous to 3 ft or more. In clays, the subsoil should appear well-fissured and have no hard compact layers that will restrict root range and impede movement of water. Sandy soils may have very compact subsoil layers and sometimes iron and humus pans. Where compact layers or pans occur in subsoils within reach of a subsoiler, cultivator, buster or mole plough, they should be broken when the soil is dry, at intervals of 3 ft or less, and in two directions for good effect. Pans or tight layers below the reach of these implements can still adversely affect crops, though progressively less the deeper they lie. Gravelly soils may have thick layers cemented tightly together by deposits of iron hydroxides. These may need heavier equipment to break them up and some are almost unbreakable except by explosives.

Soil Profile

Information on the soil profile is obtained from auger borings or from soil pit as already described (see page 3). Normally, the soil should be examined to a depth of 3–4 ft.

The profile may be almost uniform in colour and texture throughout, or it may comprise successive bands (horizons) one below the other and different in colour, texture and structure. Generally speaking, uniformity of colour, particularly brown or grey-brown, throughout the profile indicates soils of excellent quality and potentiality, whereas soils showing marked changes in colour or more obscure mottling at different levels in the profile are suspect. It is important to decide what the colour differences are due to, and to note the depth of top soil and the depth of freely drained soil (if drainage is impeded). These matters are dealt with more fully in the following sections.

Soil Colour

The colour of soils is derived from organic matter and soil minerals, coatings or layers of iron hydroxides, and the effects that aeration, wetness, water movement and acidity has had on them. It is possible to gain useful information on recent and past soil conditions from a study of colour changes down the profile. Experience and knowledge is needed to interpret the colours and colour changes seen and only a brief exposition is given here.

A dark brown surface soil gradually changing to a uniform warm brown colour extending with little change to a depth of 3–4 ft, indicates a well-drained soil and suitable conditions for deep rooting. Black types of organic matter indicate wetness or past wetness and, in sandy soils, present or past acidity. Mixtures of colours — brown with grey — indicate impeded drainage or periodical wetness with poor or bad aeration; a lot of rusty markings indicates serious wetness either past or present. Uniform greyness or blue-greyness indicates intensive wetness and anaerobic conditions of short or long duration. Pale, washed-out colours or whiteness may indicate acidity or past acidity, or springs or moving ground water particularly if some rust mottlings are also present. Colour differences due to defective drainage need to be distinguished from the often more striking ones seen in the subsoil, as a result of the presence of unweathered geological material. Here the change in colour is so obvious that there is no cause for confusion. Nevertheless, the presence of unweathered material anywhere near the soil surface is undesirable for other reasons.

Soil Drainage

Drainage of water through soils is through the larger pores and fissures. Apart from the effects of situation, heavy or unstable textures and defects in structure are the chief causes of impeded drainage or wetness. These matters have already been mentioned as well as the diagnostic value of soil colours. Among the latter, greys and grey-blue shades are the most reliable for they indicate recent wetness; whiteness, rusty markings or concretions are fairly permanent in soils and may equally indicate wetness that is quite recent or that no longer exists.

The symptoms of defective drainage need to be looked for carefully, and the depth at which they occur should be noted. Sometimes the signs are faint or, because of the natural colour of the soil, they may be masked or difficult to detect. As a practical guide, the following scale of drainage in relation to depth should prove suitable for many crops:

Bad	Top 6 in. freely drained; very impeded below
Poor	Top 12 in. freely drained; very impeded below
Fair	Top 18 in. freely drained; impeded below
Good	Top 24 in. freely drained; impeded below
Very good	More than 24 in. freely drained

Water that is brought into a soil as ground water by springs may sometimes be an asset, but at others damaging to crops, depending on its position and the conditions that it produces in the soil above. That is why the optimum depths for ground water vary according to the texture of the soil. Thus, for example, a water-table at a depth of 20–24 in. is good with a sandy loam, whereas it should be at 30–36 in. with a silty loam, and at 40–44 in. with a clay loam.

With so many factors affecting the drainage and moisture disposal of soils, it is very necessary to assess the causes of impeded drainage, the variations in levels and intensity that occur at different seasons, and the likely effects on crops, before steps are taken to improve the drainage of soils.

Crops vary considerably in their tolerance of impeded drainage in soils. On the whole, however, it is winter crops, deep rooted crops and rapidly growing young stands that are prone to damage from poor drainage, and some specially sensitive crops such as cauliflowers and some salad and root crops. Some diseases such as club root of brassicas and foot rot of leguminous crops seem to be worse on wet soils and under high rainfall.

Soil Depth

Some points about soil depth have been discussed under soil drainage. The ease or otherwise of auger boring gives information concerning the nature and suitability of the soil. Soils formed from drift materials, e.g., glacial tills, wind-blown deposits, downwash and alluvium, are open in structure and easy to bore into throughout their depth, and the soil core may only half-fill the auger. Soils formed *in situ* from older geological materials are often highly compacted due to compression of the parent material during its long history; they are usually difficult to bore into and more so at depth, and the soil core tightly fills the auger.

The importance of this is that openness provides facilities for free drainage and root development at depth, and drift soils as a class include some of the deepest and best soils for all crops, such for example as the brickearths and river valley alluvial soils.

On sloping sites, the top of the slope may be eroded through downwash, giving rise to poor drainage and wetness in winter, but in summer droughtiness due to shallowness and poor root development. Conversely, at the bottom of the slope or where a cross-bank or hedgerow has intercepted downwash, deeper soil and better conditions of drainage may be found.

Soil Organic Matter

Organic matter in soils is of two main kinds, one which may be called fibrous consisting of the recognizable remains of plants, and another which may be called humus consisting of the broken down structureless remains of plants. In arable soils the organic matter is usually distributed fairly evenly within the depth of ploughing, and in old arable soils the amount of fibre may be very small and the total amount of organic matter very low — under 2 per cent. Free drainage, good aeration and nutrient supply (especially nitrogen) are most desirable for crops, but they also promote the activity of soil organisms that destroy organic matter. If the organic residues left by crops are low, as they often are, continuous arable cultivation can lead to the gradual loss of organic matter, particularly from soils of open texture.

Under grass, accumulation of fibre or humus takes place because root development continues for a longer period of the year and suffers less from disturbance of the soil.

Adverse soil conditions, such as severe acidity, periodical wetness or rapid drying during summer, prevent or retard decay and result in the excessive accumulation of fibre. Black humified organic matter may similarly accumulate as a result of unsuitable types of decomposition under adverse soil conditions. The kind and distribution of organic matter in soils under grass is thus a reflection of root development and fertility levels and of possible defects in soil structure, drainage, acidity, moisture or nutrient supply.

On the better soils, organic matter is a well-balanced mixture of dark brown humus and fibrous root remains and the structure of the soil is porous and granular to a depth of 9–12 in. Such features in a soil almost certainly indicate good structural condition, with good drainage and nutrient supply and lack of serious acidity. Productive grass or lucerne ley is usually an indication of favourable soil conditions, and of suitability for vegetable crops, provided the soil texture is also suitable.

Nutrient Levels and Acidity

Vegetable crops, particularly those with a short growing season, require readily available nutrients. They vary in their susceptibility to acidity but a slightly acid condition is favourable to all. The main nutritional problems are acidity and the levels of phosphate and potassium, for all of which a fair assessment can be made by soil analysis. Other problems are magnesium deficiency, particularly when potassium and calcium are very high, which can be very damaging to carrots; manganese deficiency in alkaline soils with black types of organic matter; iron deficiency in alkaline soils that are close textured; and boron deficiency in alkaline soils low in organic matter which can badly damage brassicas, celery and swedes. These problems are diagnosed by the symptoms they produce, the response of the crop to nutrient sprays applied to the foliage (see page 30) and by soil examination. Soil analysis plays a limited and often indirect part.

Summary of Points in Soil Assessment

The main points in the assessment of a soil for vegetable production may be summed up as follows:

Soil Texture. Examine the moist (not wet) soil by feel between thumb and forefinger. Polishing of the surface and moulding indicates clay. Smoothness or silkiness indicates silt or organic matter, which can be distinguished from one another by soil colour. Grittiness indicates sand.

Soil Structure. Poor tilth, impeded drainage, caking of the surface and running of the soil indicate poor structure. If the soil is clay, it should be well drained, open, and show a structure of fine fissures; unsuitable clay is compact, plastic and structureless, like "pug".

Soil Profile. Good signs are uniformity of colour, particularly warm brown throughout, and absence of "horizons", indicating satisfactory aeration and drainage.

Soil Colour. Colour changes and colour mixtures are always suspect. Grey or rusty mottling or rusty concretions and markings indicate drainage defects. A sudden change from a darker surface soil to a lighter colour below may indicate wetness, high acidity or compactness in the subsoil, or the organic matter may be confined to the surface. White sand grains indicate extreme acidity, either past or present, and may be associated with micro-nutrient problems.

Soil Depth. Note particularly the depth of top soil, depth at which drainage is held up or to which water-table rises in winter, the point at which mottling or other colour changes occur, or concretions have collected. Note the depth at which a cultivation pan or hard subsoil or underlying rock layer is detected.

Nutrient Status. Chemical analysis for phosphate and potash status is important, as deficiencies are common in land newly brought into vegetable production. Extremes of pH may indicate possible troubles from micro-nutrient deficiencies or toxicities.

VEGETABLE GROWING AREAS AND THEIR SOILS

Although market gardening has extended throughout England and Wales, there are certain areas which can still be regarded as the home of the industry. These areas are mainly in Kent, Surrey, Sussex, Cornwall, Worcestershire, Essex, Bedfordshire, Cambridgeshire, the Fen basin behind the Wash, Cheshire, Lancashire and Yorkshire.

Very Sandy Soils

In these soils single-grained sand particles predominate. The individual particles can generally be seen and can easily be felt between the thumb and forefinger. When wet they can be formed into a ball but crumble readily when touched.

Coarse-grained sandy soils dry early in the spring and warm up sooner than soils containing higher proportions of silt and clay. They are often prized for their earliness, but they are not suited for crops that are grown during the warmest part of the growing season.

Coarse sandy soils are naturally infertile and have a low moisture holding capacity, whereas the finer-grained sandy soils have a higher water holding capacity and are, therefore, much more satisfactory for vegetable growing. The addition of organic matter greatly improves the moisture status of these light soils.

Sandy soils are used for vegetable growing in the Lower Greensand areas of Surrey and Sussex. The sands are deep and often excessively drained and irrigation is widely practised. A range of vegetable crops is grown and extreme specialization is uncommon. In Bedfordshire and Cambridgeshire, a wide range of vegetables is grown on very sandy soils on upland areas of the Lower Greensand. The cropping and management problems are similar to those on the sandy soils of Surrey and Sussex.

West of Abingdon in Berkshire sandy soils derived from the Calcareous Grit of the Corallian formation are especially useful for carrots. In the Pershore area in Worcestershire, acid and potash-deficient coarse sandy loams derived from Keuper sandstones are used for a wide range of crops.

Alluvial and wind-blown sands in the Vale of York and other sands in the Vale of Pickering are used for specialist carrot production. When these soils contain less than 4 per cent of clay they are subject to wind-blowing, while those with a clay content greater than 8 per cent are unsuitable for carrots. Marling with a calcareous clay from the Keuper Marl is sometimes practised to bring the clay content between these limits. Such marling also adds considerable amounts of lime to soils which are naturally acid. In south-west Lancashire vegetable crops are grown as part of the farm rotation on black humus sands overlying shallow quartz sands sometimes excessively drained. Near Formby on the Lancashire coast between Southport and Liverpool an interesting development has been the reclamation of blown sands for the cultivation of asparagus.

Sandy Loams

Sand particles predominate in this class of soils but they also contain enough silt and clay to give them a more stable structure. When moist they can be formed into a ball which does not crumble as easily as one made from a sand.

Sandy loams are more retentive of moisture and nutrients than are sands, and although not quite as early, they are considered to be more suitable for vegetable growing. Both sands and sandy loams can be worked soon after rain or irrigation without ill effects on tilth. This is a great advantage in early preparation of the soil and in keeping weeds under control by cultivation during the growing season.

Vegetable crops have been grown for many years on the sandy loam soils derived from Tertiary deposits (Thanet Beds, Woolwich, Oldhaven and Blackheath Beds) in the Sandwich, Ash and Swanley areas of Kent. In the Swanley area especially, some of the soils are pebbly and thin and overlie chalk at no great depth. Many of the vegetable growing soils of the Lower Greensand of Surrey and Sussex are sandy loams.

Intensive vegetable production is carried out in the river valleys of the Thames and its tributaries especially in Berkshire, Buckinghamshire, Middlesex and Surrey. Many of the soils are dark brown sandy loams, freely or excessively drained, but badly drained soils are also found. The growth of London is tending to force the market garden industry out of the Thames valley into areas such as the Lower Greensand.

In Bedfordshire, mixed vegetables are grown in river valleys on sandy loams derived from the Lower Greensand and boulder clays. In east Norfolk and west Suffolk and Cambridgeshire, carrots and peas are the main crops on stony sandy loams derived from glacial drifts.

In north Worcestershire soils derived from Keuper and Bunter sandstones support a wide variety of crops. In the Severn valley the river terraces provide well-drained soils on level sites. These deep coarse sandy loams or loamy sands, stony and with little structure, overlie marl at well below 3 ft from the surface. Drainage is free or even excessive, so that the numerous types of crops grown may suffer under droughty conditions.

Sandy loam soils are found around Cottingham, the centre of Dutch-light growing in the East Riding of Yorkshire. Many of these soils have been dressed heavily with "night soil" and town waste. In Lancashire, sandy loams on the alluvial and river terrace soils are used for vegetable growing around Walton-le-Dale and the Ribble estuary between Preston and Southport. Some of these soils are dark coloured and of high fertility, due to additions of organic matter over a long period. Level sites and artificial drainage have made many of these soils very attractive for market garden work.

Gravels

The gravels are very stony types of sandy soils and sandy loams. The stone is usually rounded or angular flint and varies considerably in amount. Crop productivity depends on the proportion and nature of the material between the stones, and on the water supply. Gravels may be acid or alkaline, and they are naturally low in potash; they respond well to additions of farmyard manure. A wide range of vegetables is grown on them, particularly in river valleys and terraces in east Suffolk, Norfolk, Cambridgeshire, Hertfordshire and along the Ouse valley in Bedfordshire and Huntingdonshire.

Loams

Loams are intermediate in texture between sandy loams and clays and contain roughly equal proportions of sand, silt and clay. They become cloddy when worked too soon after rain but break down fairly easily when dry. They are not ideally suited for intensive market gardening but nevertheless are excellent soils for general purposes. Loams are retentive of both moisture and nutrients and include some of the most valuable brickearths and alluvial soils. As a class they are among the most fertile soils of the country and, with proper management, almost any crop can be grown on them.

Many of the areas already mentioned as having mainly sandy loam soils (e.g., the Thames valley), also have loamy soils devoted to vegetable production. In the Lower Greensand in Kent south of Maidstone vegetables are grown on a range of soils including stony loams and deep light drift soils.

Loamy soils predominate in the Faversham, Sittingbourne and Isle of Thanet districts of Kent. Market gardening is combined with the growing of fruit and hops on deep loams (brickearths) in the Faversham and Sittingbourne districts and with arable farming on the shallow loam soils of the Isle of Thanet. Brickearths are found on the coastal plain of west Sussex, which enjoys a favourable situation and climate for vegetable crops. Loams of brickearth type are also used in east Norfolk and south-east Essex, for growing a wide range of vegetable crops. Brickearths are very suitable for a wide range of vegetables (other than the earliest crops) but are liable to cap on the

surface following heavy rain and this can adversely affect the germination of small seeds.

Most of the soils used in Devon and Cornwall for vegetables and flowers are well-drained loams derived from shales, sometimes with basic igneous intrusions. In most parts of the extreme south-west of England, a favourable situation is at least as important as the nature of the soil. The site should have a sunny aspect with shelter from frost and wind, and the main soil requirements are earliness and good drainage. On the steep land in both counties the fields are small and often terraced, or there are scattered pockets or patches of well sheltered early land, but larger scale production combined with mixed farming is found in Cornwall between Camborne and Truro, and in the neighbourhood of St. Austell, Wadebridge and St. Columb, and in Devon around Kingsbridge.

In Yorkshire, loam soils are used for market gardening in the lower and middle reaches of the valleys of the Aire and Calder. When these alluvial soils are free from the risk of flooding they are potentially very fertile, their chief defects being deficiencies of lime and humus. Patches of loamy soil also occur in the East Riding in the Howden and Goole areas and in the Cottingham area, and similarly textured soils are found associated with the sandy loams in Lancashire described previously.

Silts

These differ from loams in containing a higher proportion of silt and very fine sand. They are very retentive of moisture and when dry form rather hard clods which are not very easily broken down. When the soil particles are very fine, the soil may become impervious to surface water and behave like clay. The particles also tend to run on the surface and cake hard on drying. Silts are often more fertile than sands or sandy loams, and will grow heavy crops of excellent quality but they are not generally recommended for intensive work.

In the fen-silt areas of Lincolnshire, Isle of Ely and Norfolk, vegetable crops are grown on a range of silty soils. Some of the brickearths in east Norfolk and south-east Essex are also silty in texture. The fen silts are mostly deep soils with good drainage, which is maintained by pumping and piping. The brickearths are either naturally well-drained or piped. Both types are very productive provided they are well manured and organic matter is maintained at a moderate level. Silty soils are also used for market gardening in many of the alluvial areas of Yorkshire and Lancashire.

The mixed sands, silts and clays of the Hastings Beds form the central core of the counties of Kent and East Sussex. Some vegetables are grown on the lighter soils of the Tunbridge Wells and Ashdown Sands, on which silty soils predominate. In the natural state these soils are acid and deficient in plant foods and due to the predominance of very fine sand and silt tend to cap on the surface.

Clay Loams

These soils contain a high proportion of clay which makes them very retentive of moisture and sticky when wet. When dry they form hard clods which can only be broken down with difficulty. Clay soils are not normally chosen for market gardening, but where adequately drained they are successfully utilized for growing vegetable crops, particularly brassicas.

In upland areas of the counties of Essex, Hertford, Cambridge, Bedford,

Huntingdon, Norfolk and Suffolk, Brussels sprouts and cabbage are grown on clay loam soils derived from Boulder Clay which is mostly chalky. In Essex, alluvial clay loam derived from London Clay and resting on it are also used for these crops. In valleys north of the Chalk in Cambridgeshire and Hertfordshire, Brussels sprouts and cabbage are grown on heavy chalk marls, and on heavy alluvium derived from the Chalk and Gault Clay.

In the Vale of Evesham on the Lower Lias limestones and clays, the most extensive soil is the Evesham series, which is a calcareous heavy or clay loam with a well-developed granular structure, which makes it particularly suitable for asparagus as well as for a wide range of annual vegetable crops.

Brussels sprouts are widely grown on quite heavy soils overlying Oolitic Limestone at no great depth in an important area extending from Gloucestershire and Worcestershire to west Oxfordshire.

The chief soil type in the market garden area of the West Riding of Yorkshire is that derived from Coal Measures sandstone and shale. In its natural condition the shale soil consists of a stiff badly drained clay. This unpromising material has been reclaimed for market gardening in the past by the addition of large quantities of "night soil" and more recently with destructor ash and screened household refuse.

Peaty Soils

The term peat is used indiscriminately for soils which naturally contain a high proportion of organic matter. These soils are brown or black in colour, rich in nitrogen, usually low in mineral elements especially potash. They can absorb many times their own weight of water and are loose, friable and easily worked after rain. The Lancashire and Cheshire peats are naturally acid, while the fenland peats are variable but mostly alkaline.

In the fen-peat areas of the counties of Huntingdon, Isle of Ely, Cambridge, Suffolk and Norfolk, celery, carrots, peas and parsnips are the principal crops. The peats vary considerably in depth, mineral matter content, acidity, and their tendency to dryness or "drumminess". They may be very acid and in need of heavy liming, or they may contain free chalk and give rise to manganese deficiency. Most of the vegetable growing is on the lighter types, classed as light peats to peaty loams; they may be deficient in potash and are very responsive to soluble phosphate.

Acid peats and highly organic soils are extensively used for vegetable growing in the moss lands of Lancashire. Much of the area between Blackpool, Preston and Southport lies on peat, and vegetable crops, especially cauliflowers, lettuce and celery, are widely grown. Acid peats are also found around Irlam and various other localities in Lancashire, and are much used for market gardening and especially celery growing.

Soil Organic Matter

It is generally recognized that the organic matter content of soils should be maintained at a high level in order to build up and maintain the fertility necessary for the growth of market garden crops. The organic matter in soils consists of the remains of plant and animal life in varying stages of decomposition. Thus part may consist of undecomposed roots, leaves, stems, stubble and dead animal remains and part as the decomposed material known as "humus". The organic matter content of poor sandy soils may fall as low as 1–2 per cent, but in heavy soils the percentage is usually much higher. The amount also varies with depth, decreasing as the subsoil is reached.

EFFECTS OF ORGANIC MATTER

The beneficial effects of organic matter in the soil are very complex and are due mainly to the humus portion. Humus has two important physical properties, it can absorb many times its weight of water and in addition it has powerful cohesive properties. A good humus content thus affects the water holding capacity of sandy soils and this is particularly noticeable during times of drought, while the cohesive properties of humus are of value in sands and light soils where the pore space and aeration are generally too great. Another physical property of humus is that it darkens the soil; dark soils that are rich in humus tend to warm up quickly in spring, and are thus of value in promoting early seed germination and early cropping.

One of the most important effects of organic matter in the soil is the maintaining or building up of a desirable crumb structure. Generally speaking this means the aggregation of the ultimate particles of soil into crumbs, which are of a size to give suitable pore spaces for the retention of moisture but allow the draining away of excess water, the free movement of air and the easy penetration of roots; a good crumb structure remains stable under repeated wetting and drying and resists crushing by farm implements, tractors and animals. Good soil structure and aeration favour root development and penetration of roots into the soil and this with the improved water holding capacity enables plants to withstand drought conditions more readily.

Organic matter is the only form in which nitrogen can be stored in the soil and its gradual decomposition by micro-organisms results in the liberation of ammonia, which is converted into nitrate and thus provides available nitrogen for the growth of crops. In addition other plant nutrients such as phosphorus, potassium, calcium, magnesium and micro-nutrients may be present and become available to plants as decomposition proceeds in the soil. Humus also acts as a temporary storehouse for nutrient elements that are applied to the soil or released by decomposition. Most of the living organisms in the soil require organic matter and soils which are active biologically are usually of high fertility.

There is a loss of organic matter from all cultivated soils, and this is increased by aeration and liming. Consequently, market garden soils which are intensively cultivated and heavily limed lose their organic matter quickly.

A certain amount of humus is produced from crop residues left in the soil but this is usually insufficient to make up for the losses. Thus in order to maintain soil fertility, losses must be made good in other ways.

BREAKDOWN IN THE SOIL

Humus is chemically very complex and contains a little over half its weight of carbon, while the nitrogen (N) content is about one-tenth that of the carbon (C). Plant or animal material added to the soil has a wider C/N ratio than 10:1 usually, and micro-biological activity is greatly increased after such additions. As a result carbon is lost as carbon dioxide, but nitrogen may be locked up in the tissues of the organisms decomposing the organic matter, with the result that large additions of material with wide C/N ratios reduce the "available" nitrogen content of the soil. The C/N ratios of some materials added to the soil to supply organic matter are as follows:

Material	*C/N ratio*
Young Clover	10:1
Rotted Farmyard Manure	20:1
Green Rye	40:1
Straw	80:1
Sawdust	400:1

Materials consisting of plant remains with a C/N ratio of about 40:1 or more require additional nitrogen to decompose them. With such materials, therefore, the decomposition is best carried out in a compost heap to which nitrogen is added, rather than in the soil from which soil nitrogen may be removed and temporarily locked up.

The process of rotting fresh farmyard manure in a heap reduces the C/N ratio and produces "short" manure which is more easily broken down in the soil.

MAINTAINING THE SUPPLY

In the past the maintenance of organic matter in market garden soils was due mainly to the use of large quantities of farmyard manure, chiefly as stable manure. One ton of manure contains about 3–4 cwt of organic matter; when added to the soil it decomposes rapidly and large dressings are needed to increase the humus content of the soil. Few market gardeners, however, are now able to obtain sufficient quantities of farmyard manure and other means have usually to be adopted to maintain a desirable level of organic matter in the soil.

Farmyard Manure

Farmyard manure is an excellent organic supplement since its C/N ratio is fairly narrow and decomposition has already begun. It varies greatly in quality depending on: (i) the kind of animal producing the manure, (ii) the nature and amount of litter used, (iii) its state of decomposition. Thus horses produce manure that ferments quickly with considerable heating, whereas the dung of cattle and pigs ferments more slowly, remains cold and lasts longer. Farmyard manure containing much undecomposed straw or other litter is known as "long" manure, whereas manure which has been allowed to break down in a heap is said to be "short". As already explained the effect

of rotting down farmyard manure in a heap is to narrow the C/N ratio and hence speed up the process of decomposition when it is added to the soil. Long manure has beneficial opening effects on heavy soils or soils liable to cap on the surface, but is best applied well in advance of cropping, say in the autumn on land to be cropped in the spring. Short manure should be used immediately before sowing or planting. When very strawy manure is ploughed in, it is advisable to add 2–3 cwt sulphate of ammonia per acre to supply the nitrogen needed for decomposition to take place. Litters such as wood shavings or sawdust decompose very slowly in the soil and manure containing these materials should be stacked with the addition of a substantial amount of nitrogenous fertilizer to aid decomposition before application to the soil (see Sawdust on page 21).

To minimize losses if farmyard manure has to be stored in the open, a compact deep heap should be built on firm level ground, and each cartload should be drawn over the heap to ensure consolidation. Finally the sides and ends should be trimmed and added to the heap and soil added to make a roof-shaped top. Considerable losses of mineral nutrients take place from manure exposed to the leaching action of rain.

Farmyard manure varies considerably in its content of manurial constituents, but on an average it contains about 0·5 per cent nitrogen (N), 0·25 per cent phosphoric acid (P_2O_5), and 0·5 per cent potash (K_2O). Thus a normal dressing supplies considerable quantities of plant nutrients but it would be misleading to assume that any dressing would be equivalent to fertilizers supplying the same amounts of nitrogen, phosphate and potash. A large proportion of the nitrogen in dung is locked up in organic forms which are not readily available to crops, and in addition some nitrogen is inevitably lost to the air. Although dung supplies phosphate and potash these are less available than those in fertilizers.

It is commonly assumed that farmyard manure reduces the need for applications of nitrogenous fertilizers. Although some nitrogen in dung is available to the crop (except in strawy manure), it is usually unnecessary to reduce the amount of nitrogenous fertilizer given unless the dressing of dung is very heavy or the quality of the crop likely to suffer from excess nitrogen. On the other hand with heavy applications of dung, fertilizer dressings may be scaled down, especially on market garden soils which have received generous dressings of fertilizers in the past (see pages 39 and 42). On agricultural land recently turned over to intensive market garden cropping, however, it would be safer to continue to give normal amounts of phosphatic and potash fertilizers.

Deep-litter Poultry Manure

Deep-litter manure is obtained from poultry kept under intensive systems in deep-litter houses and open strawyards. In these systems the floor is covered with litter which is added to when necessary and allowed to remain for a period of one or more years. In effect the litter is composted with the droppings. Stirring may be carried out during the winter months to prevent crusting on the surface. It is inadvisable to add lime as this causes a loss of nitrogen in the form of ammonia; the addition of a little superphosphate on the other hand will help to conserve nitrogen. Well-made samples of deep-litter manure are relatively dry and friable and easy to spread on the land.

A wide range of materials, depending upon cost and local availability,

has been used as a source of litter, including straw (whole or chopped), chaff, peat-tailings, sawdust and wood shavings. Difficulties which arise when sawdust or wood shavings are added directly to the soil (see page 21) can be overcome if these materials are first turned into deep-litter manure.

The manurial value of deep-litter poultry manure depends upon such factors as the age and type of bird producing the manure, nature of the litter and length of time it has been in the house, and in particular whether or not the manure has been exposed to rain, as in open yards. Well-made samples may be regarded as a valuable bulky organic manure with much higher percentages of nitrogen, phosphate and potash than farmyard manure. An "average" sample of one-year-old deep-litter manure might contain 2 per cent nitrogen, 2·5 per cent phosphoric acid and 1·2 per cent potash. Material produced in open strawyards might contain 0·5 per cent nitrogen, 0·4 per cent phosphoric acid and 0·5 per cent potash.

Straw

The increasing shortage of farmyard manure has caused some market gardeners to turn to straw as a source of organic matter. Straw may either be ploughed directly into the soil or partly decomposed first in a compost heap. When raw straw is ploughed in, nitrogen is withdrawn from the soil during the process of decomposition and this may result in a temporary shortage of nitrogen in succeeding crops. To prevent this happening, 1 cwt sulphate of ammonia per ton of dry straw should be broadcast before the straw is ploughed in. There are mechanical difficulties, however, in working large amounts of straw into the soil and in practice it is better to compost the material first.

*Straw Composts**

Well-made straw compost is an excellent substitute for farmyard manure and is easy to handle and to incorporate in the soil.

The requirements for the successful composting of straw are water, air and a supply of available nitrogen. Thorough wetting is required and up to 800 gal of water per ton of dry straw may be needed to achieve this. Straw is much easier to wet if it can be purchased well in advance of composting and left exposed to the weather for several months. When new straw is used some form of sprinkling device facilitates wetting.

The source of nitrogen may be inorganic, such as sulphate of ammonia or "Nitro-Chalk", or organic such as dung, urine, poultry manure or domestic sewage sludge. About 1 cwt sulphate of ammonia or "Nitro-Chalk" per ton of dry straw is required, and if sulphate of ammonia is used about 1 cwt ground chalk or limestone should also be added to the heap. If domestic sewage sludge is used, about 3–4 parts of wet sludge ($1\frac{1}{2}$ parts of sludge dry matter) is needed to 1 part of dry straw. Alternatively the contents of domestic cesspools may be pumped on to the straw stack.

Compost heaps should, if possible, be built in a sheltered situation away from drying winds. They may be of any convenient shape provided that they are not too high or too narrow. The heap is built in layers each about 12–18 in. thick giving a finished height of 5–6 ft after allowing for settling. Over-compaction excludes air from the heap and should be avoided. The "Nitro-

* For garden composts made from vegetable and other plant residues, see page 74.

Chalk" is scattered on each layer of straw, but sulphate of ammonia (if used) should be applied to every other layer and alternated with the dressing of lime. Water is given to each layer, the amount required depending on the original moisture content of the straw.

Similar principles are followed in the making of straw-sewage sludge composts, layers of straw alternating with layers of wet sludge, and water being added to moisten the heap evenly. About ¾ ton of wet sludge per 100 sq. ft of straw, 15 in. deep, will be required. Heaps are best constructed in a long narrow shape, say 4 yd wide and with an initial height of 5–6 ft. Heaps of this size and shape provide a good balance between aeration and exposed surface.

Within a few days the heap heats up and the composting process begins. If the heap shows signs of overheating extra water should be given, and the heap should never be allowed to dry out during the composting process. After 4–6 months the compost should be ready for use, the unrotted straw on the edges being used in the next heap. If desired, composting may be speeded up by turning the heap and giving extra water when needed.

Green Manuring

Another way to supply organic matter is by green manure crops grown specifically for ploughing-in. For this purpose mustard, rape, rye and Italian ryegrass are commonly used and also leguminous crops such as clovers, vetches and lupins which have the additional advantage of "fixing" nitrogen from the air. On market gardens there are often unsaleable crop residues which can also be ploughed-in to supply organic matter. If the green crop is young, it has a narrow C/N ratio and decomposes rapidly in the soil. This may result in some improvement of soil structure and a rapid release of nutrients, but usually with little lasting increase in the humus content. If the crop is more mature and of wider C/N ratio, decomposition is slower and there may be a greater contribution to the humus content.

It is difficult, however, to make a substantial contribution to the organic matter content of the soil by green manuring, for the ploughing-in of an average crop containing 1 ton of dry matter per acre will add about 0·1 per cent to the soil organic matter, and of this amount only a small fraction will ultimately form humus. The beneficial effects obtained from green manuring are due largely to the prevention of loss of nutrients from the soil by leaching and the release of these nutrients following ploughing-in of the crop. Green manuring makes phosphorus and potassium more available for crop production, whilst with leguminous crops large amounts of nitrogen are also produced. To make full use of the nitrogen, the ground should be quickly sown or planted after a green manure crop has been ploughed-in; otherwise losses from the soil may be heavy.

Amongst market gardeners there is a general reluctance to grow green manure crops because of the loss of saleable produce, although summer-sown catch crops put in after early potatoes or green peas are often a practical possibility. Mustard sown broadcast in August at 20 lb per acre should be ready for ploughing under in the autumn. Rape sown in July at 10 lb per acre broadcast, or 6 lb drilled, can be ploughed under in the autumn or spring. Mustard and rape are both cruciferous crops and for this reason they should not be sown on market garden soils infected with club root; otherwise, they may help to perpetuate the disease between one

brassica crop and the next. Italian ryegrass sown from July to September at the rate of 30–40 lb per acre broadcast gives quick growth and the root fibre left behind may help to improve soil structure. Very late sowings of Italian ryegrass, however, are likely to give good results only in south-west England. For the above crops manuring with nitrogenous fertilizers is often necessary to ensure rapid and luxuriant growth. Phosphatic and potash fertilizers are unlikely to be needed on old market garden soils but if fertility is being built up on poor ground they may be required.

Leys

The excellent soil structure of good grassland is due to the extensive penetration of roots throughout the soil and the build up of organic matter from dead and dying roots. The growth of a grass crop for one or more years gives the soil time to recuperate from the effects of continuous cultivations. The longer a grass ley is down, the greater the benefits. The roots alone may contribute over 1 ton of dry matter per acre per annum and this together with the turf eventually returned to the soil adds materially to the humus content.

How far market garden land can be rested in this way depends on many factors, of which economics is generally the main consideration. Instances are known of successful inclusion of a one-year ley following a corn crop in an arable rotation where a large area of vegetables is grown, allowing the ground to go down to grass about one year in eight. If an early summer cut of hay is taken, the second cut disced (and possibly dunged) and ploughed-in forms an excellent preparation for a gross feeding crop the following year.

If it is decided that leys are a practical proposition, the value of cocksfoot deserves attention because of its vigorous root system and bulk of organic matter produced. Italian ryegrass and broad red clover makes a satisfactory one-year ley. Maximum improvement of soil structure is obtained from longer duration leys.

Sewage Sludge

In some places domestic sewage sludge is available as a source of organic matter. There are two types, namely, raw sludge in various stages of dryness, and digested sludge. The latter is produced from primary sludge which is subjected before drying to a process of "digestion" which reduces its bulk and results in a product that is easier to dry. The wet sludge is allowed to dry in lagoons or under-drained drying beds freely exposed to air; in this way the moisture content of the sludge may be reduced to about 50 per cent and in very dry periods to 30 per cent. The average percentage composition of the two common types of sludge is given in the following table.

	Dry Matter *per cent*	*Organic Matter* *per cent*	*Total Nitrogen* *per cent*	*Phosphoric Acid* *per cent*	*Potash* *per cent*
Raw Sludge	40	20	0·9	0·5	0·1
Digested Sludge	52	23	1·4	1·1	0·2

The organic matter is different in its nature from the strawy fibrous material found in farmyard manure and is probably not so effective in improving the structure of heavy soils. Sludges should mainly be regarded as sources of organic matter but they do also supply some nitrogen, which is useful in composting. Sewage is usually applied at 20–50 tons or more per acre according to moisture content, or it may be used for composting straw.

Sludges from industrial sources should not be used in heavy dressings until their safety and potential value have been established, and before use technical advice from the National Agricultural Advisory Service should be sought. There may be a high content of iron and other heavy materials, and if chromium, zinc and copper are present direct toxic effects may occur with crops.

Town Refuse

Town refuse is a very variable material depending largely on whether glass, tins, waste paper and other debris have been removed, and how much waste vegetable matter is present. In winter the amount of coal ash and cinders is high with a low percentage of vegetable matter, while in summer the position is reversed.

There are two main types of refuse; screened dust, which is refuse passed through a screen with meshes about $\frac{3}{8}$–$\frac{1}{2}$ in., and pulverized refuse in the preparation of which scrap metal, bottles, etc., are first removed and the remainder is then pulverized. Pulverized dust contains a little more organic matter than screened dust, and experiments have shown pulverized dust to be more effective although both are less effective than equivalent amounts of farmyard manure.

Town refuse used at rates of 20–30 tons per acre supplies some organic matter, and on heavy soils the cinders and ash may improve the working of the soil. Small but varying amounts of nitrogen, phosphate and potash are present but these should be disregarded in considering dressings of fertilizers for market garden crops. The ash of screened or pulverized dusts contains appreciable quantities of carbonate of lime and dressings of 20–30 tons may contain the equivalent of 15–30 cwt.

Shoddy

This is wool waste from the Yorkshire mills. The highest grade obtainable from pure wool contains 12–15 per cent nitrogen, but there is usually some admixture of cotton and dirt which gives rise to the most commonly available medium grade materials containing 5–10 per cent nitrogen, and sometimes poor samples with as little as 2·5 per cent nitrogen. An analysis for nitrogen is clearly a safeguard in buying this material. The physical condition is also important, for a loose friable sample can be spread much more evenly than a matted one. Oily samples may break down slowly in soil, and release nitrogen slowly. Shoddy has a good reputation as a nitrogenous manure, and is popular in the Kentish hop gardens and orchards, and also in the market garden districts of Bedfordshire. It is useful for its water-holding capacity. It should be spread and ploughed-in in winter. The dressings range from half a ton for the best quality to 1–2 tons of the more common grades, which supply as much organic matter as 10 tons of farmyard manure and considerably more nitrogen.

A warning must be given as to the possible danger of anthrax from the use of shoddy. One of the two following precautions should be taken:

1. Only shoddy guaranteed to contain no foreign element should be used. British shoddy is comparatively safe; or
2. Only shoddy that has been sterilized should be used.

Although there is no obligation on the seller to state the percentage of

nitrogen in a consignment, the price asked is usually related to the nitrogen content either assumed or determined by analysis.

Feathers and Fur Wastes

The nitrogen content of feathers is variable and may be as low as 3 per cent, but a good sample contains about 8 per cent. Small feathers are easily decomposed in the soil, but large ones are more persistent and less active. When obtainable they are applied at about 1 ton per acre.

Rabbit waste consists of the ears, feet and tail of rabbits, and is a useful organic fertilizer containing about 10 per cent of nitrogen and some phosphate. Supplies are small, and a little is imported. Hair waste breaks down and releases nitrogen very slowly, owing to its matted condition, and is less useful than feathers.

Brewery Residues

Spent hops and malt culms are bulky organic manures which, used in quantity, may benefit the physical state of the soil. Their chief nutrient is nitrogen, though the amount of phosphate in some samples is quite appreciable. Spent hops is the residue after hops have been extracted with water in the brewery. In their wet state they contain about 75 per cent water, 0·6 per cent nitrogen, 0·2 per cent phosphoric acid. The moisture content varies considerably according to circumstances, and the analysis expressed on the dry matter is the most satisfactory figure. On this basis the nitrogen content ranges from 2–3 per cent and phosphoric acid is about 1 per cent.

Spent hops are regarded mainly as a source of organic matter, but they contain some nitrogen. In their wet condition they may be used in the neighbourhood of the breweries rather in the same way as farmyard manure, or they may be composted. Composting is an important use for such material, but care must be taken with heaps of spent hops because they can heat up rapidly during the process of decomposition and may even catch fire spontaneously. When some of the water is removed, and organic or inorganic nutrients are added, the products are known as hop manures. For commercial crops a rather moist material graded up with organic supplements and often with inorganic potash is used. For small scale purposes and where storage in bags is essential dry material with inorganic supplements is preferred.

Malt dust (malt culms) is the by-product which results when malt is kilned. The rootlets and shoots which sprouted during the malting process are shrivelled up by the heat and removed by screening. Malt dust normally contains about 10 per cent water and 3½ per cent nitrogen.

Spent Mushroom Compost

This material, which is readily obtainable by the vegetable grower in some areas, is of variable composition mainly depending upon the proportion of casing soil which it contains but the following figures show the range of composition which may be expected.

	N	P_2O_5	K_2O
		lb per wet ton	
Farmyard Manure	12	5	12
Spent Horse Manure Compost (excluding soil)	17·5	6	20
Spent Horse Manure Compost (including soil)	8·8	3	10

The organic matter of spent mushroom compost is generally more decomposed than that in strawy farmyard manure and hence it may be less valuable for opening heavy soils or the prevention of capping on soils which are subject to this trouble.

Other points which may arise in the use of this material, more especially when repeated heavy dressings are given, are as follows:

(*a*) Many batches contain large amounts of lime, especially where chalk and peat from casing are mixed with the compost. This can induce micro-nutrient deficiencies (see page 27) in susceptible crops on some soils.

(*b*) Materials used in pest control may occasionally be present in sufficient amount to be harmful to crops to which spent compost is applied. For example, BHC may cause tainting in root crops, and DDT is highly toxic to cucumbers and related crops. It is possible that new insecticides and fungicides will supersede those in use at the present time and it is advisable for users of spent compost to watch developments in this field.

Except for the risk of adverse effects from over-liming on some soils, these objections are likely to be of little consequence to the vegetable grower who gives periodic dressings of spent mushroom compost to outside land, and it can be a useful source of organic matter.

Sawdust

As a source of organic matter sawdust has one advantage as a waste material, namely, that it is locally available at little or no cost. Unfortunate experiences in the past have led growers to be wary of using it in large quantities and there is a prejudice against sawdust from softwoods, which experimental work has shown to be unjustified. Fresh sawdust varies in pH from about 3·5 to 7·0 according to the kind of trees from which it is derived, and if worked into the surface soil causes temporary nitrogen shortage and so depresses the yield of crops, even when nitrogen is added as "Nitro-Chalk" or sulphate of ammonia.

The most satisfactory material is produced by rotting sawdust down before spreading, either by composting it in heaps with nitrogen at the rate of about 3 cwt "Nitro-Chalk" per ton of dry sawdust, or by using it as litter in poultry-houses.

Sawdust has been used as a surface mulch in soft fruit plantations to smother weeds, and has been considered for use with certain vegetable crops such as Brussels sprouts and asparagus, but its use may lead to shortage of nitrogen in the soil which can be corrected only with difficulty over a long period, and the growing of vegetables on such sites is likely to lead to trouble.

Miscellaneous

In certain coastal areas seaweed is used to supply organic matter and it is also a valuable source of potash. Peat is a useful soil improver but is too expensive to use on a large scale. Organic manures such as hoof-and-horn, dried blood, meat-and-bone, have little if any direct effect on the humus content of the soil, but it should be borne in mind that a high level of manuring resulting in heavy crop yields will provide correspondingly larger crop residues for ploughing-in, and thus help to maintain the level of organic matter in the soil.

Mineral Nutrition

WITH the exception of carbon and oxygen, plants obtain the elements they require for growth and development from the soil. These enter plants in solution through the root hairs. Plants absorb whatever is available to them in the soil and they commonly contain elements for which no useful function has yet been proved. So far as is known, of the elements absorbed from the soil only thirteen are essential. These are nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, boron, manganese, molybdenum, zinc, copper and chlorine. One other element, sodium, is useful to some plants and of little value to others. The chloride content of common salt (sodium chloride) is damaging to certain plants.

Potassium, calcium, magnesium, iron, manganese, copper and zinc are absorbed from the soil in a simple condition uncombined with other elements whereas nitrogen, phosphorus, sulphur, molybdenum, boron and chlorine are absorbed in the form of nitrate, phosphate, sulphate, molybdate, borate and chloride respectively. Nitrogen may also be absorbed in the ammonium form.

It is seldom that a soil is completely deficient in any of the nutrient elements. Commonly, however, soils are unable to provide all the elements at rates sufficient for normal growth of crop plants and the natural supply of some elements has to be supplemented in the form of fertilizers or farmyard manure. Thus nitrogen, phosphorus, and potassium must usually be added as fertilizers, magnesium sometimes, boron and manganese occasionally, but molybdenum, zinc and copper rarely.

The absorption of a particular element may be decreased or increased by the presence of other elements. Some of these effects are of importance in practice. For example, high calcium may reduce the absorption of potassium and boron and cause deficiencies of these elements which would not occur on less calcareous soils. High potassium may reduce the absorption of calcium and help to prevent lime-induced chlorosis on calcareous soils. It may also reduce the absorption of magnesium and accentuate a condition of magnesium deficiency. Experience shows that troubles due to lack of balance of nutrients in the soil are fairly common and it is worth while bearing this in mind when considering rates of application of lime and fertilizers.

The functions of the elements in plant nutrition are only partly known. Nitrogen, phosphorus and sulphur are known to be constituents of the complex organic products of which the plant is built up. Others play some intermediate part in these building-up processes, without appearing as constituents of the final products, e.g., potassium, iron, manganese and copper. Magnesium is a constituent of chlorophyll, the green colouring matter of plants. All the elements are not equally mobile within plants. Calcium, boron, iron and copper appear to move more slowly than other elements into the young formative tissues (such as stem growing points and cambium) or are retained more strongly by older tissues. Deficiencies of these elements may, therefore, check or seriously disturb normal growth.

The major nutrients are those which are needed in relatively large amounts for the normal growth of plants. They include nitrogen, phosphorus,

potassium, calcium, magnesium and sulphur, but not all of these need to be included in the normal manuring of crops.

For full crop production, three major nutrients are added in comparatively large quantities in routine fertilizer treatment, namely, nitrogen, phosphorus and potassium. Calcareous soils provide ample natural supplies of calcium, but in other soils the practice of liming meets the plant's needs for calcium and also performs other functions in the soil itself. In practice, additions of magnesium are most likely to be needed on sandy soils receiving little or no farmyard manure.

Sulphur deficiency has never yet been recorded in this country, and it need not be taken into consideration in practical manuring. It should, however, be realized that considerable quantities of sulphur are regularly being added to the soil in the form of NPK fertilizers, such as sulphate of ammonia, superphosphate and sulphate of potash.

MAJOR NUTRIENTS

Nitrogen

The chief sources of nitrogen in the soil are organic matter, ammonium salts and nitrates. Part of the importance of organic matter lies in the fact that nitrogen in this form can be stored in the soil. Both ammonium salts and nitrates are formed in the soil by decomposition of organic matter; they may also be added as nitrogenous fertilizers. Nitrates are readily removed by drainage water but ammonium salts hardly at all. In normally fertile soils, however, ammonium salts are rapidly converted to the more mobile nitrates. Losses of nitrogen as nitrate in drainage water are commonly high, especially from heavily manured soils.

Nitrogen in plants occurs largely in organic combination. It enters plants through the root hairs, mostly as inorganic nitrate, and moves readily as such to all parts of the plant. With most plants nitrate is absorbed throughout the life of the plant but most rapidly during periods of rapid growth.

An acute deficiency or excess of nitrogen affects the whole of the plant. Deficiency leads to slow growth, undersized pale green leaves and reduced flower and seed formation. It is important to realize, of course, that the depth of green colour is not always a reliable indication of the nitrogen level in plants; manganese-deficient plants, for example, may also have pale yellow-green leaves.

Excess nitrogen affects the top more than the root and leads to rapid vegetative growth, large dark green leaves, reduced flower and seed formation, and soft tissues liable to injury from frost, handling or disease. Control of nitrogen supply throughout growth is thus one of the most important factors affecting the quality of the crop. When a crop has a long growing season, heavy applications of nitrogenous fertilizers may in the early stages of growth produce undesirable effects or, on the other hand, may be lost from the soil in drainage water before the crop can use them. Thus it may often be better not to attempt to satisfy the full demands for nitrogen when the crop is sown or planted but to give a proportion during growth as top dressings.

Because of the connection between nitrogen and vegetative growth, an adequate supply of nitrogen is especially important for crops such as cauliflower which need to grow rapidly.

Absorption of nitrate by plants may affect the intake of other elements and some of the effects are of importance in practice; for example, crops may show symptoms of magnesium deficiency when the nitrogen intake is low, and in such cases the deficiency may be checked by applying nitrogenous fertilizers. Instances of this kind occur in wet seasons and on soils low in organic matter and nitrogen. As a rule the level of magnesium in the soil should be increased as well as the nitrogen supply.

On soils that are deficient in available potassium, deficiency symptoms of this element may appear more readily when the level of available nitrogen is high. The increase in size of top and foliage, which the nitrogen brings about, increases the demand for potassium and other elements. The practical answer is to maintain the balance between the various nutrients by the correct use of fertilizers.

Phosphorus

Phosphorus occurs in soil mainly as phosphate, the greater part of which is not readily available to crop plants. Furthermore, iron and aluminium reduce its availability in acid soils. A small amount of phosphorus occurs in organic combination as a constituent of soil organic matter and in this form it is often not very available to plants and must first be converted to phosphate. The amount of phosphate in the soil solution is minute and movement of phosphate through the soil is practically negligible.

Applied phosphates rapidly revert to less available forms in many soils, and it is for this reason that methods of placing phosphatic fertilizers in bands 2 or 3 in. away from the germinating seeds are being developed. This has the effect of delaying the reversion of the phosphate because it is less intimately mixed with the soil. Again it is often of value to work a small dressing (the so-called "starter" dressing) of an immediately available phosphatic fertilizer into the soil just before seeds are sown. Phosphorus has a particularly stimulating effect on root development and is valuable for promoting rapid root growth during the early stages of establishment of a crop; hence the importance of having sufficient soluble phosphate in the soil, and of applying soluble phosphate fertilizers before sowing or planting quick-maturing crops.

Because of its associations with growth, a deficiency of phosphorus results in small size of plant, slow growth and dull leaves. The leaves tend to be bronzed or dull purple in contrast with the brighter pale yellow and red tints associated with nitrogen deficiency.

Phosphorus stimulates the ripening processes and tends to reduce the vegetative period of growth. Provided ripening is not premature so that crop yield is reduced (as may happen when excessive quantities of phosphate are given), these effects of phosphorus are often an advantage.

Potassium

Potassium occurs in soils mostly in the clay minerals and, in general, clay and loam soils contain more potassium than sandy soils. In the soil potassium is released slowly and the amount immediately available to crops is usually small. Movement of potassium in soils is also slow and losses in drainage water are small except on very light soils or land that has been heavily manured with potash fertilizers. On calcareous soils the excess calcium may accentuate deficiency.

Potassium is essential for growth and development and has an important

function in reducing water loss by plants. Thus it is of value in dry or shallow soils in helping to offset the effects of a moisture shortage.

When plants are deficient in potassium the older leaves suffer first and usually show a paling of the margin followed by a greyish-brown scorch. Growth is checked and stunting follows.

Under dull light conditions when excess nitrogen would cause growth to be soft, potassium helps to prevent it to some extent. It is important to ensure that potassium is not deficient during growth and for many vegetable crops a high intake is desirable to avoid soft growth and susceptibility to frost and mechanical injury. Thus adequate potash manuring is essential to produce hard growth in crops which have to stand through the winter.

Sometimes a high intake of potassium by plants results in a reduced intake of magnesium and the appearance of symptoms of magnesium deficiency. This problem can usually be dealt with by applying magnesium compounds to the soil, and when the potassium level in the soil is very high, by also withholding potash for several seasons until the balance is restored.

Calcium

Calcium is an important element in all soils, occurring in a variety of minerals of which the commonest are calcium carbonate, calcium silicate and calcium sulphate. Calcium derived from these minerals is adsorbed on clay and organic matter and a proportion occurs in the soil solution as calcium bicarbonate and calcium sulphate in which forms it is removed from the soil in drainage water. This loss in drainage water is continuous, but it is greatest in regions of high rainfall and in soils that are heavily manured with ammonium salts. It ranges from 2–10 cwt of calcium carbonate per acre per annum. There is also a substantial removal of calcium in crops that are sold off the farm, and is highest with heavy crops, particularly brassicas.

When the losses of calcium are not made good by liming, acidity develops in the soil. On acid soils crops may suffer in a number of ways depending on the crop concerned. Some crops develop characteristic symptoms directly due to the deficiency of calcium, while others show symptoms of injury due to an excess of elements such as manganese and aluminium which are particularly soluble under acid conditions. The practical solution to these problems is liming with materials such as calcium carbonate (ground chalk or limestone), calcium hydroxide (hydrated lime) or calcium oxide (burnt lime). Calcium can also be added to the soil in fertilizers such as superphosphate and bones but the effect of these materials on acidity is only slight.

Excess calcium on naturally calcareous or over-limed soils may reduce the intake of boron, iron and manganese and induce deficiency of these elements.

In addition to its role in plant nutrition calcium has important functions in the soil which are discussed on pages 44–46.

Magnesium

Magnesium occurs in soils in various forms which pass into the soil solution as magnesium bicarbonate or magnesium sulphate. Magnesium is lost more slowly from the soil than calcium. Some losses occur in drainage water and by crop removal. Absorption of magnesium by the roots of plants is rapid during active growth, but almost ceases as maturity is approached. Hence the need for adequate magnesium in the soil during the early stages of growth of a

crop, and the difficulty of dealing with magnesium deficiency when it occurs near maturity.

Magnesium enters plants fairly readily and is very mobile within the plant. A deficiency is marked by general paleness of the leaves and extensive interveinal yellowing, but symptoms vary greatly from crop to crop. Visual symptoms are preceded by a movement of magnesium from older to younger tissues. High intake of potassium and/or low nitrogen may result in reduced intake of magnesium and the appearance of magnesium deficiency in the crop. This usually occurs in the later stages of growth when it is difficult or impossible to correct it.

MICRO-NUTRIENTS

In addition to comparatively large amounts of nitrogen, phosphorus, potassium and calcium, plants need for healthy growth small quantities of other elements, often referred to as trace elements or micro-nutrients. Difficulty in growing some crops has been shown to be related to a deficiency or, occasionally, an excess of one or more of the following: boron, copper, iron, manganese, molybdenum and zinc. For instance, marsh spot in peas is caused by insufficient available manganese in the soil, and brown heart of swedes and turnips follows a lack of boron.

All plant species do not have the same need for every micro-nutrient. For example, brassicas are sensitive to boron and molybdenum deficiency, whereas parsnips, peas and beans are sensitive to manganese deficiency. Climatic conditions also may affect the availability of individual micro-nutrients. For instance, boron deficiency is made worse by drought.

A further consideration is that deficiency symptoms in plants may be produced either because there is a real lack of the required elements in the rooting medium, or because soil acidity or alkalinity may have the effect of making micro-nutrients unavailable to plants. Iron, manganese and boron deficiencies are usually found on naturally alkaline soils or on those which have been made alkaline by an excessive dressing of lime. Unlike these elements, molybdenum usually shows most severe deficiency under acid conditions, and some degree of control can often be achieved by liming, provided there is some molybdenum in the soil.

Some deficiency diseases of vegetable crops, known to occur in other countries, have not yet been seen here. For example, copper deficiency has only been diagnosed on cereal and fruit crops in Britain, but it is known on vegetables in other countries.

The general position with regard to micro-nutrient deficiencies in vegetables may be summarized as follows: Boron and manganese problems are quite well known under special conditions. Molybdenum deficiency is less common, being almost confined to a few brassica crops, whereas iron deficiency is rarely seen in vegetables. Zinc deficiency, as with copper, is still unknown as a problem in vegetable production. A look-out should be kept for these possible troubles.

As knowledge of crop nutrition increases, other mineral deficiencies or excesses in extremely small amounts may prove to be the cause of unexplained harmful effects in plants. Detailed knowledge of the range of requirements and of crop varietal reaction is still scanty, but the progress referred to below has been the outcome of keen observation in the field

oupled with pot experiments and laboratory studies at research stations.

Boron

Many soils in this country seem to contain sufficient boron for plant life. ts availability is sometimes reduced by temporary dryness after a wet winter r spring, or by high soil alkalinity, or as the result of over-liming. Crops rown on light-textured alkaline soils are very susceptible to deficiency.

The deficiency symptoms in vegetable crops are various and sometimes so rikingly characteristic that a descriptive name is given to the resulting ondition, such as cracked stem in celery, canker in table beet, and brown eart in swedes.

Brassicas are very susceptible, the symptoms being death of the growing oints, distortion and tinting of leaves and necrosis of the stem which may ecome hollow. Cauliflower shows browning of the curd or it may fail to evelop any curd. Turnips and swedes show a speckled browning throughout e flesh of the roots, which become fibrous and in acute cases, hollow. In eet the skin becomes roughened and canker develops on the roots near round level. In celery, the stems become brittle and transversely cracked nd there is brown mottling of the leaves. In root crops other than turnip or wede, infection by secondary organisms may follow and lead to rotting of e tissues. Spraying with a solution of borax may be effective but soil pplication is generally preferable. A soil dressing of 20 lb borax per acre efore planting or sowing is an effective control with most crops. In order to nsure even distribution of this small amount the borax should be mixed with and or fertilizer. It should not be mixed with sulphate of ammonia. Borax ay be applied to row crops as a side-dressing at the same rate. Care must be aken not to apply a greater quantity than 20 lb per acre or toxic effects may e produced. For this reason compound fertilizers containing borax should nly be used in strict accordance with recommendations. Potatoes and cereal rops are particularly subject to boron toxicity.

Manganese

Manganese deficiency is fairly widespread. It may be due to a natural hortage of manganese in the soil, but it is more usually induced by the ombined effect of a high pH (above 6·5), a high content of organic matter nd poor drainage. The soils where these conditions are found include:

Manganese shortage absolute

Strongly leached pebbly or sandy soils.

Manganese shortage induced by soil alkalinity *

Alkaline peats and peats overlying calcareous subsoils.
Alluvial soils with high water-tables.
Some heavy soils with impeded drainage (e.g., soils derived from Gault or Lias Clays).
Heavily-manured old garden soils and newly-ploughed old grassland, containing too much lime.

The symptoms of deficiency vary considerably from one crop to another, nd is not always easy to distinguish from iron deficiency which is, however, are in vegetables (see page 29). Manganese deficiency usually shows more

* The alkalinity may be natural or due to over-liming, the bringing of calcareous subsoil to e surface, or the addition of lime-containing organic residues (see page 21).

clearly in the older leaves, whereas in iron deficiency the younger leaves are affected first. Manganese-deficient potatoes exhibit distinctive dark spots on the leaflets along either side of midrib. Seeds of peas and beans show brown spots on the cotyledons (marsh spot). Globe beet has erect rather sparse leaf rosettes and dull purplish leaves. Susceptible vegetable crops include globe beetroot, peas, parsnip, lettuce, potatoes and dwarf beans.

Prevention or cure is comparatively simple. Growing crops showing symptoms in the early stages of growth may be dusted with finely ground manganese sulphate at 20–60 lb per acre, or sprayed with a solution containing 4–8 lb manganese sulphate per acre in low (20 gal) or high (100 gal) volume of water per acre. A single spray is often sufficient to give a good commercial control but it may sometimes be necessary to spray twice. The addition of a suitable wetter helps especially with plants with waxy leaves, e.g., brassicas. To control marsh spot in peas the crop should be sprayed once or twice during the flowering period. When leaf symptoms of deficiency have been seen, an earlier spraying should be given in addition as soon as the trouble is noticed.

An excess of manganese is often a problem on strongly acid soils. The symptoms in potatoes, runner and dwarf beans are rather similar to those caused by a deficiency. Soil sterilization by steaming, especially when the soil is acid, leads to an increase in water-soluble and exchangeable manganese and so may produce toxic effects on plants.

Molybdenum

Unlike boron and manganese, deficiency of molybdenum usually occurs on acid soils, because this element is less available to plants under acid conditions. Provided there is sufficient molybdenum in the soil the addition of lime to an acid soil encourages uptake of this nutrient and to some extent deficiency may be controlled by this means.

The only crops known to be seriously affected in this country by molybdenum deficiency are brassicas, especially cauliflower and lettuce. In cauliflower the curd fails to develop and the leaves are distorted and reduced, until in severely affected plants only bare midribs and small knobs of deformed leaf remain, a condition known as "whiptail". Milder symptoms are an early interveinal chlorosis of older leaves, which may be very largely accompanied in severely affected plants by browning of the edges of the young leaves which then develop into the characteristic whiptail form.

Control is by the use of sodium molybdate either as a soil dressing or as a spray. The quantity required is very small, about 4 oz per acre as a soil dressing, or 4 oz in 100 gal water per acre (0·025 per cent) as a spray. Care must be taken not to apply more than the recommended dose as plants may be damaged by solutions containing as little as 1 lb/100 gal. Molybdenum seems to be needed early in the life of the plant, so that spraying moderately sized seedlings in the seedbed with a 0·025 per cent solution or watering the seedbed before sowing with a solution giving about 1 oz sodium molybdate per 20 sq. yd is beneficial.

Copper

Copper deficiency occurs either naturally, or as a result of over-liming in certain soils. Some peat and fen soils are specially liable to give rise to copper deficiency, and its frequent occurrence on organic heathland soils brought into arable cropping has caused it to be known in the Netherlands as

'Reclamation Disease". It can also occur on poor acid sands and gravels.

No instance of copper deficiency in vegetables has been recorded in this ountry, but on some of the light sandy soils and fenland peats in East Anglia t has been a serious problem in cereal crops.

Treatment consists in giving soil dressings of copper sulphate but the rate f application depends on the type of soil and proportion of organic matter. On some soils as little as 7 lb per acre of copper sulphate is sufficient, and too nuch may prove toxic. Advice on treatment, particularly on rate of dressing er acre, should be sought for local soil conditions. Alternatively, crops may e sprayed with a solution of 8 oz copper sulphate crystals in low (20 gal) r high (100 gal) water per acre, but there is a risk of corrosion of equipment nd scorching of foliage unless the water is hard. It is safer and easier to use 2 lb per acre of cuprous oxide or copper oxychloride.

Iron

Although nearly all soils contain sufficient iron for the needs of crops, under ome conditions it may not be in a form which can be utilized. Deficiency s most often induced by an excess of lime in the soil, but it may also be due to xcesses of other elements, such as manganese, zinc or chromium, occurring ither naturally (e.g., zinc in the Mendip Hills of Somerset or manganese in cid soils), or in some industrial wastes and sewage sludges.

Iron deficiency affects perennial crops most seriously, and is rarely seen in egetables. The symptoms usually take the form of a yellowing of the younger eaves which in severe cases may become almost white.

At present there is no really economic method of treatment for vegetable rops, and the trouble is therefore serious when it does occur; under such onditions susceptible crops are best avoided.

Zinc

Zinc occurs in most soils in amounts sufficient for the needs of most plants, ut its availability may be reduced by excess of lime or phosphate. So far inc deficiency has not been found in vegetable crops in this country although t is known in fruit trees. If it should occur, the treatment is to spray with a olution of 8 oz zinc sulphate crystals per 100 gal water per acre.

On the other hand, a natural excess of zinc in the soil, notably on the Mendip Hills of Somerset, causes chlorosis of field crops due to induced iron eficiency. The remedy is to avoid growing susceptible crops, such as lettuce r tomatoes.

Sodium and Chlorine

Sodium is seldom an important constituent of soils in this country except when sodium chloride (common salt) occurs in soils which have been flooded y sea water or where the ground water is affected by seepage from the sea. Sodium has harmful effects on the structure, aeration and drainage of soils y reducing the stability of soil aggregates.

Sodium is present in all plants but its role in plant nutrition is not very lear. It plays some part in the nutrition of sugar beet, increasing both the ield and the sugar content of the roots. Sodium appears to reduce water oss and flagging of the foliage in dry weather and this effect may be of mportance with brassicas and some other crops. To a limited extent it ppears to be able to replace potassium as a nutrient. In view of the uncertain

effects of sodium on crops it should only be used as a fertilizer on those crops which have been shown to benefit from it in field experiments.

Chlorine has been shown to be an essential micro-nutrient for plants, but as chlorides are present in fertilizers such as muriate of potash and in rain-water, deficiency is unlikely to occur in the field. Chlorides affect the moisture and dry matter content of potatoes and in excess are damaging to soft fruit crops such as red currants and raspberries. Chlorides are not held by any soil constituent and pass out more or less rapidly in drainage water.

FOLIAGE SPRAYING

Plants are able to absorb a wide range of soluble substances through their leaves. The mineral nutrients, with the exception of iron, are readily absorbed and utilized, visible responses often appearing in older leaves or in new growth in a matter of days. From the point of view of vegetable production, there are several possibilities in the use of foliage sprays:

As a means of diagnosing deficiencies with a view to correct treatment;
To correct a mineral deficiency rapidly, when applications to the soil are likely to be ineffective or too costly;
As a means of applying nutrients when the soil is too dry for rapid response to top dressings.

The chief disadvantages of foliage sprays, apart from the general problems associated with spraying field crops, are:

Rain after spraying may wash the nutrient off before it has been completely absorbed;
Failure to act through loss by run-off from leaves difficult to wet;
Risk of injury to the crop, or loss of appearance for market.

Foliage sprays may cause serious injury to crops if used incorrectly. They may also cause spotting of the foliage, and so reduce the value of the crop. In practice, sprays may be applied at 20–100 gal per acre, using a wetting agent but the rate of application of the nutrient salts per acre must not be varied suitable rates per acre are given in the table below. Special care is needed since the margin between the required dose and the toxic level is often small and serious damage may result if the correct strength is exceeded. Hydrated lime may be added to copper sulphate, manganese and zinc sprays to lessen the risk of damage. If there is any doubt about the safety of a spray, it is advisable to spray a small test plot before dealing with the whole field.

Salts known to be suitable, and the suggested strengths at which they should be used are given in the table. Foliage sprays should only be applied when a deficiency is known to exist.

Strength of Foliage Sprays

For application at the rate of 20–100 gal per acre

Element	*Material*	*Amount per acre*
Boron	Borax ($Na_2B_4O_7$, $10H_2O$)	1–2 lb
Copper	Copper sulphate ($CuSO_4$ $5H_2O$)	8 oz
	Copper oxychloride ($CuOCl_2$) or cuprous oxide (Cu_2O)	2 lb
Magnesium	Epsom salts ($MgSO_4$, $7H_2O$)	20 lb
Manganese	Manganese sulphate ($MnSO_4$, $1H_2O$)	4–8 lb
Molybdenum	Sodium molybdate (Na_2MoO_4, $2H_2O$)	4 oz
Zinc	Zinc sulphate ($ZnSO_4$, $7H_2O$)	8 oz

Many of the micro-nutrients, and also magnesium sulphate, may be incorporated in certain insecticidal, fungicidal and herbicidal sprays, but the advice of the manufacturers of such materials should be sought before this is done.

As a rule, nutrients should be given singly; the idea that an "omnibus" spray may be used to deal with all possibilities is risky in practice.

Fertilizers are occasionally sold which have been "fortified" by the addition of micro-nutrients. Although these may be of value in special areas and on particular farms, their general use cannot be recommended, because any variation from the standard rate of application of the fertilizer also alters the rate per acre at which the micro-nutrient is being applied. In any suspected case of micro-nutrient deficiency, it is well to obtain technical advice before taking action.

Fertilizers and Manures

NITROGENOUS MANURES AND FERTILIZERS

As has been stated earlier, nitrogen is used by plants largely to build up protein in leaves and roots. The forms in which it is available are both organic and inorganic. The rate of release of nitrogen from organic forms is usually said to be slower and more protracted than it is from ammonium salts or nitrates, and consequently crops have a more uniformly distributed nutrient supply throughout the growing season. This property and the fact that there is no build-up of salts in the soil with organics makes them safer to use, but nitrogen in inorganic fertilizer can usually be used satisfactorily if the need for greater care in application is understood. Organic nitrogenous materials provide a means of giving a steady supply of nitrogen over a long period. Furthermore, application is not attended by the risks of scorching the plants that may result from top dressings of inorganic fertilizers.

The effect of organic manures used in quantity is not confined to the first crop, but useful residues may persist in the soil for subsequent crops. It has been shown, however, that nitrification of some organic nitrogenous fertilizers — notably hoof-and-horn — takes place very much more readily than has been realized hitherto, and that different samples of individual materials such as bonemeal may vary considerably in their rates of nitrification.

In the accompanying table the relative availability of the nitrogen in a number of organic materials is shown. This has been measured by the percentage of nitrification in soil over a period of about a month, using the nitrification of sulphate of ammonia as the standard of comparison (i.e., percentage nitrification of sulphate of ammonia in soil = 100 per cent). The figures show that there is little to choose over this period of time between meat-and-bonemeal, hoof-and-horn, and dried blood, whereas with leather meal only about half the nitrogen becomes effective over several weeks, and in other wastes and by-products nitrogen is made available so slowly as to be almost useless to crops.

Relative Availability of Nitrogenous Manures

(Standard: Sulphate of ammonia 100)

Meat-and-bonemeal	91	Plastic by-product	10
Hoof-and-hornmeal	89	Chrome tanned leather	7
Dried blood	89	Bark tanned leather	Nil
Treated leather meal	45		

Measurement of the rate of nitrification in soil using a similar range of fertilizers has shown that hoof-and-horn, sulphate of ammonia and dried blood have nearly the same rate of nitrification for the first week, but that after that time the rate of change of each is different. The fineness of grinding of materials, such as hoof-and-horn and bonemeal, affects the availability of the nitrogen in them.

Although bonemeal is predominantly a phosphatic fertilizer, it contains a useful amount of nitrogen, the amount of which varies from sample to sample (2·0–5·5 per cent N). Bonemeal contains varying quantities of true hard bone (mostly calcium phosphate) and of soft bone, cartilage and bone marrow, which contain a higher proportion of water-soluble nitrogen than the hard bone.

The value of horticultural produce is judged as much by stage of maturity and quality as by yield, and it is widely believed that the required conditions are more easily achieved by the use of organic manures than by fertilizers. The belief that organic manures have a special value is reflected in the fact that they are in demand for the production of high value crops despite the expensiveness of the nutrients they contain. Be that as it may, it is none the less true that many satisfactory and productive crops are being produced with the use of fertilizers alone, or occasionally supplemented by some form of bulky organic manuring. These various claims have so far not received critical examination in the field, partly on account of the difficulty of obtaining a precise measure of quality with horticultural crops, but some work on these lines is now being undertaken by the experimental horticulture stations of the N.A.A.S.

Organic Manures

Organic manures as sources of nitrogen include bulky manures, concentrated manures and waste products. The bulky manures have a special value as a source of soil organic matter for the maintenance of soil fertility and a good physical condition of the soil. In addition many of them, e.g., farmyard manure, are useful sources of nitrogen and sometimes other nutrients (see page 15). Other bulky manures and residues which also supply nitrogen include shoddy, feathers and fur wastes, and brewery wastes. (Full details are given on pages 19–22.)

Many of the concentrated organic materials of value as nitrogenous manures are also in great demand as animal feedingstuffs, and the better grades are used for stock-feeding, leaving the lower grades to the manure market. The most widely used of these materials are hoof-and-horn, meat-and-bonemeal and fishmeal. The two last-named also contain substantial amounts of insoluble phosphoric acid, and therefore have some value as sources of phosphate, which is dealt with in a later section. Some other bone manures contain much more phosphate than nitrogen and are for all practical purposes phosphatic manures (see pages 41–42).

As regards the available nitrogen supply, 1 cwt hoof-and-horn is about

equivalent to $1\frac{1}{2}$ cwt fishmeal or 2 cwt meat-and-bone. When the material used also contains a substantial amount of phosphate, it would be reasonable to reduce the normal rate of dressing of superphosphate provided the soil is highly fertile.

There are also a number of organic waste materials that may have some value as sources of nitrogen, though they are not comparable with the concentrated manures but should be judged on the content of readily available nitrogen and the absence of constituents injurious to plants.

Hoof-and-horn

Finely ground hoofmeal, hornmeal and the mixture hoof-and-hornmeal are highly regarded as nitrogenous manures for horticultural purposes. Since the horticultural demand is considerable prices are high and supplies restricted. Commercial grades of hoof-and-hornmeal contain 13 per cent nitrogen, and the phosphate content is negligible. Availability depends on the fineness of grinding, and both very fine and very coarse are less useful than a well-graded mixture.

Dried Blood

Dried blood is one of the most active of the concentrated organic manures, but the best grades, containing up to 14 per cent nitrogen, are in demand as animal feedingstuffs. The common grades offered as manure contain 10–13 per cent nitrogen, which is quickly nitrified in the soil. Samples vary in quality or solubility with the method of drying which may be by direct heat, steam or vacuum low-temperature process. The last yields a crystalline material of the best quality. It is particularly popular with tomato growers and is frequently included in the more expensive compound fertilizers intended for high quality intensive production.

Oil Cakes and Meals

The residues from the manufacture of vegetable oils by the pressing of seeds of rape or castor are useful as nitrogenous manures when obtainable. Castor meal is harmful as a stockfeeding material, but it contains 5–6 per cent of nitrogen and finds a ready outlet as an organic manure. Rape cake (5 per cent nitrogen) used to be popular as a fertilizer on farm land and occasionally comes on the market in small quantities. Both materials are sometimes included with inorganic constituents in mixed fertilizers as conditioners to improve their physical state.

Guano

This material is a product dug from natural deposits in the almost rainless parts of the world, especially South America. A good sample contains 10–14 per cent N with 9–11 per cent P_2O_5. The term has been applied loosely to the excrement of any birds, but poultry manure, either fresh or dried, is not guano. Guano varies in composition and is liable to deterioration if not stored away from rain. The nitrogen is rapidly available and its nitrification in soil is almost as rapid as with sulphate of ammonia. It has long been popular for horticultural crops.

Poultry Manure

Poultry manure is variable in composition and in the fresh state may contain 70 per cent of water, but only about 8 per cent if kiln-dried. The wet material is difficult to handle and even distribution is a problem. Ammonia

is easily lost in storage and some is lost on kiln-drying. There is a risk of ammonia-scorching of young plants if too heavy applications of the fresh material are used. The dried material is easier to handle and a more uniform product is obtained which is safer to use. The average composition of the fresh material is about 1·5 per cent nitrogen, 1–2 per cent phosphoric acid and 0·6 per cent potash. Compared with farmyard manure, it is relatively deficient in potash and for practical purposes the potash content can be ignored (see also deep-litter poultry manure on pages 15–16). The kiln-dried product contains about 3·5 per cent nitrogen, 3 per cent phosphoric acid and 1·5 per cent potash.

Meat-and-bonemeal

The raw material from which meat-and-bonemeal (tankage) is obtained consists of waste meat, offals and condemned carcasses from the large slaughterhouses. The mixture is steamed under pressure to remove the fat, and dried at high temperature to kill disease organisms, and then ground. The grade analysing about 7 per cent N and 16 per cent P_2O_5 is a popular horticultural manure. As the proportion of bone increases, the percentage of nitrogen falls and of phosphate rises. Some samples may contain only 4 per cent N; hence a knowledge of the analysis of these materials is of great importance to purchasers.

Bonemeal

Bonemeal as distinct from meat-and-bone contains about 4 per cent N and 22 per cent P_2O_5 (or even more). It should generally be regarded as a phosphatic manure (see page 42) although its nitrogen content is not negligible.

Fishmeal

This material consists of fish offals or fish unsuitable for consumption, from which the oil has been removed. It contains 7–10 per cent nitrogen and 4–10 per cent phosphoric acid with less than 1 per cent potash. The lower-grade samples are sometimes known as "fish guano". It is a useful fertilizer for vegetable crops, both alone and as a constituent of compound fertilizers.

Leather Waste

Some types of leather waste may contain up to 12 per cent of nitrogen, but only a small proportion of it may be available to plants. The value of leather as a source of nitrogen for crops depends very much on the kind of tanning process which it has undergone. Untanned or oiltanned scraps, such as those resulting from glove manufacture, are useful for vegetable crops on heavy land, whereas the processes of bark- or chrome-tanning make the nitrogen almost unavailable to crops. Excessive use of certain chrome-tanned materials may lead to damage of crops by chromium poisoning. Leather meal which has been specially treated to improve the availability of the nitrogen is often used as a conditioner or drying agent in compound fertilizers.

Plastic Residues

Small quantities of waste products from the manufacture of buttons and other moulded articles are occasionally offered for sale as suitable nitrogenous organic fertilizers. These should only be used after obtaining expert advice or as the result of field trials, because although the nitrogen in protein materials such as casein is reasonably available to plants, that in casein treated with formaldehyde or in some synthetic plastics is often almost

entirely unavailable. For example, one such material containing 22 per cent nitrogen was found to have only about one-tenth the effectiveness of dried blood.

A range of synthetic plastic materials containing varying proportions of nitrogen such as urea-formaldehyde compounds has been produced in the U.S.A. for use as fertilizers, and experimental work on their value is in progress. It does not seem that materials at present available can be relied on to provide a synthetic source of steadily available nitrogen in the same way as meat-and-bone and hoof-and-horn manures. Many release nitrogen at much too slow a rate.

Soot

This material has for long been popular with growers especially in Bedfordshire, Kent and Cheshire. It usually contains 1–6 per cent nitrogen as sulphate of ammonia, which accounts for its stimulating effect on crops. In addition, other properties are claimed, such as darkening the soil and improving its physical condition making it warmer and earlier; it is also regarded as a deterrent of slugs, snails and other pests.

Soot varies considerably in composition according to the source. The fluffier and blacker material from domestic flues is much superior to that from boilers and furnaces. Raw soot should not be used as it often contains tarry materials which damage plants, but on storage for 3–6 months chemical changes take place which make it harmless.

Nitrogenous Fertilizers

In contrast to the organic manures already described, the nitrogenous fertilizers of commerce are simple inorganic salts readily soluble in water and quickly available to plants. Whenever water percolates through the land it carries some nitrogen away in solution in the form of nitrate; consequently soils in humid areas tend to become impoverished in readily available nitrogen. To make good this loss and provide crops with sufficient nitrogen for their needs, nitrogenous fertilizers are applied either in the spring seedbed or as a top dressing after the crop is through the ground.

It is important to apply these readily available forms at the right stage of growth, when they are most needed, but top dressings should not be given when conditions are too dry for the crop to be able to take up the fertilizer. The effect of adding active nitrogenous fertilizer is seen within a few days. Growth is improved, and the leaves take on a deeper green colour. Crops grown for their leaves, such as cabbage, are particularly responsive to nitrogenous dressings. There are very few soils so rich in available nitrogen that fertilizer is not required for maximum production of crops.

Sulphate of Ammonia

Sulphate of ammonia (20·6 per cent nitrogen*) is one of the most commonly used of the quickly-acting nitrogenous fertilizers. It is not quite as quick acting as those which contain their nitrogen in the form of nitrate, because ammonia has to be converted by soil bacteria into nitrate before most plants can make use of it.

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* *Note.* Under the Fertilisers and Feeding Stuffs Act, 1926, the percentage of nitrogen in a fertilizer must always be stated in the invoice: statements as percentages of ammonia, sulphate of ammonia, etc., should be disregarded. Where sulphate of ammonia is concerned, the amount of free acid expressed in terms of sulphuric acid must also be stated.

On being applied to the soil, sulphate of ammonia is adsorbed by the clay and organic matter, and to this extent it is preserved from immediate loss during wet weather. Under normal conditions, however, the ammonia is rather quickly nitrified when the soil is warm enough, and the nitrate thus formed may be washed into the subsoil if the crop is not in a sufficiently advanced stage to take it up. In the very early spring, sulphate of ammonia fails to act, because the conversion to nitrate does not take place at low temperature (below 42°F).

It is usually applied both in base dressings and in top dressings especially for leafy crops. It must not be mixed with lime or lime-containing fertilizers such as basic slag, for there will be a loss of ammonia. In top dressing, care should be taken not to scatter the fertilizer on the plants, otherwise they may be scorched or damaged.

Repeated dressings of sulphate of ammonia will in time make soils more acid, but this is easily put right by liming. The acidity produced by 1 cwt of sulphate of ammonia can be neutralized by 1½ cwt of chalk or carbonate of lime. The acidifying effect is thus not of great account, except when heavy and repeated fertilizer dressings are given. If for any reason it is not practicable to lime the land before another crop is taken, other forms of nitrogenous fertilizer such as "Nitro-Chalk" can be used in place of sulphate of ammonia.

Sulphate of ammonia is suitable for inclusion in farm-made mixtures containing superphosphate and either sulphate or muriate of potash. Factory-made compound fertilizers almost invariably contain the greater part of their active nitrogen in the form of sulphate of ammonia.

"Nitra-Shell" and "Nitro-Chalk" *

Ammonium nitrate contains half its nitrogen in the form of ammonia and the remaining half as nitrate. It therefore combines the properties of both these constituents. It has some nitrate for immediate action and the ammonia, while readily available, comes into play somewhat later. Untreated ammonium nitrate is unsuited for direct use as a fertilizer, because it takes up moisture and becomes sticky and unusable. This defect can be overcome by granulating it with calcium carbonate, which results in the production of a convenient and easily handled material.

The proprietary fertilizers thus manufactured are known under the names of "Nitra-Shell" (20·5 and 23 per cent nitrogen) and "Nitro-Chalk" (15·5 and 21 per cent nitrogen). The calcium carbonate present goes a long way to balance any loss of lime from the soil caused by the ammoniacal part of these fertilizers, which are thus very suitable for use on slightly acid soils. Their granular form makes them easy to handle and very useful for general use as top dressings but they should not be included in mixtures. Magnesium "Nitra-Shell" is also available, containing 20·5 per cent nitrogen and 7 per cent magnesium oxide.

Nitrate of Soda

This fertilizer (15·5 per cent N) is obtained by the purification of a natural salt deposit in Chile, and is now marketed in a granular form. All the nitrogen is present as soluble nitrate, which is rapidly taken up by crops.

* As "Nitra-Shell" has become available comparatively recently, it so happens that "Nitro-Chalk" is more often referred to in the text, but it should be understood that "Nitra-Shell" and "Nitro-Chalk" used in equivalent amount serve a similar purpose.

It is slightly more rapid than sulphate of ammonia in its effect and is frequently used when a crop is standing still or needs an immediate stimulus. Nitrate of soda is almost always used as a top dressing and is also useful when the soil is cold and wet in spring.

The sodium which accompanies the nitrate in nitrate of soda is of some importance. It has been shown that sodium, whether given as common salt or as sodium nitrate, is a useful nutrient for a few crops, e.g., beetroot.

On soils of unstable structure, frequent heavy dressings of nitrate of soda are likely to spoil the tilth of the surface soil; the same result follows continual and excessive use of agricultural salt. This effect is due to the sodium content of both these materials. Nitrate of soda has no tendency to make the soil acid.

Potash Nitrate

A mixed nitrate of soda and potash (15 per cent N) from Chile is sold under the name Chilean potash nitrate. The material is popular as a top dressing for market garden crops. It is as quick-acting as nitrate of soda and also contains a useful amount of potash (see page 43). The analysis varies, but a common grade contains 15 per cent nitrogen (N) and 10–15 per cent potash (K_2O).

Nitrate of Potash

This material (12–14 per cent N) also known as saltpetre, contains nitrate and potash only and is a valuable rapidly-acting fertilizer. Its chief use is for glasshouse and intensively grown market garden crops. The percentage of potash is high (about 40 per cent K_2O) so that the material is both a potassic and a nitrogenous fertilizer (see page 44).

Other Nitrogenous Fertilizers

Before 1939 several other nitrogenous fertilizers were offered to farmers, but supplies stopped during the war and have not yet been resumed to any important extent. A few notes on these and some new materials are given below.

Nitrate of Lime (Calcium Nitrate)

This fertilizer (15·5 per cent N) is very soluble in water and readily absorbs moisture from the air. For convenience of handling it is often granulated and coated. It may be used for top dressings on any type of soil, but should not be mixed with other fertilizers. As the coating is easily damaged, care is needed in handling.

Calcium Cyanamide

The nitrogen in this material (20·6 per cent N) is not immediately taken up by the plant but is converted into ammonia and then into nitrate in the soil. It is unpleasant to handle and is also caustic to vegetation. It should be applied two or three weeks before seed sowing, and is also useful as a weed-killer, and in compost-making. Calcium cyanamide supplies the equivalent of about 1 cwt calcium carbonate per cwt of fertilizer.

Urea

Urea (46 per cent N) is in use as a fertilizer in North America, but it has not so far been available on a large scale in this country, as the supply is

almost entirely absorbed by the plastics industry. Urea has been used in experimental work in this country with vegetable and fruit crops, and can be applied either as a solid to the soil or in solution as a spray on the leaves of plants. Urea for use as a fertilizer must contain very little biuret, which is toxic to plants.

Anhydrous Ammonia

The use of liquefied ammonia gas as a nitrogenous fertilizer (82·5 per cent N) is growing rapidly in the U.S.A. and elsewhere, but it has not been taken up in this country. Direct application to the soil is made through hollow tines or tubes attached to cultivator tines from cylinders, which contain the liquid under pressure, so that the gas enters the soil about 2 or 3 in. below the surface. Provided the soil is in the right condition of moisture and tilth, the gas is taken up without loss, and in fact no smell of ammonia can be detected. The value of the material as a source of nitrogen is high concentration, comparative cheapness and ease of application, either neat, or in solution in irrigation water.

PHOSPHATIC FERTILIZERS

Two types of phosphatic fertilizers are commonly applied to vegetable crops either as "straights" or in mixture:

(i) "Quick-acting" types in which the phosphate is water-soluble, namely, superphosphate, triple superphosphate, ammonium phosphate and dissolved bones, the last two containing some nitrogen in addition.

(ii) "Slow-acting" types in which the phosphate is insoluble in water, namely, basic slag, ground rock phosphate, bonemeal, steamed bone flour, meat-and-bonemeal, and some other bone fertilizers. Many of the bone materials also contain nitrogen.

The quick-acting types, such as superphosphate, are the most useful for vegetables on account of their immediate availability to the plant. Some of the organic bone fertilizers are used for their dual supply of phosphate and nitrogen, and doubtless if generous treatment has been given over a long period the release of available phosphate from the ample reserves in the soil may be adequate to meet the needs of the plants. Some basic slags are quicker-acting than the bone phosphates and are occasionally used. The ground rock phosphates have very little, if any, value for vegetables, except perhaps in the treatment of acid soil for vegetable growing for the first time.

In general, water-soluble phosphate is needed to give seedlings a good start and produce a vigorous root system. When this stage in growth has been passed less soluble forms of phosphate may be suitable. This appears to be so for many of the crops with long growing seasons, as for example broccoli, kales, Brussels sprouts, savoys and parsnips, and for others with a shorter growing season as for example, swedes, turnips, carrots, beetroot, beans and peas. There are a few crops, however, such as early potatoes, outdoor tomatoes and salad crops with a very short growing season, for which a supply of readily soluble phosphate appears to be needed throughout the life of the crop.

In a soil that has been under arable cultivation for some time, the phosphates — apart from recent applications — are fairly evenly distributed throughout the depth of ploughed and cultivated soil. There may be

ufficient phosphate in an available form for crops in this surface layer of soil, ut unless the roots can seek it out and pick it up at a sufficiently fast rate, arly growth and development may be retarded. The effect of applications of hosphatic fertilizers is to place small pockets of phosphate in the zone of urface rooting, so that the roots can feed actively as soon as they have made ontact with this phosphate. Clearly the effectiveness of the application will epend on the solubility of the phosphate, the amount applied and its nearess to the developing root system. All these factors have been studied in ecent years, particularly the placement of phosphates near the seed. In eneral, soluble phosphates are superior to others and the nearer they are laced, to within 2 in. to the side of or below the seed, the more effective they re (see also page 55).

Soils that have been recently brought under vegetable crops for the irst time usually need moderate applications of soluble phosphates or eavier applications of less soluble ones. As phosphates are applied at modere to heavy rates to successive crops year by year, or sometimes more requently, the level of phosphate in the soil gradually rises until the need for local concentration near the seed disappears and phosphatic fertilizers ecome less beneficial and may in fact have adverse effects by hastening naturity and reducing the yield. This condition is reached more rapidly vhere dung is used in addition, since the dung itself supplies phosphates and nay also make existing soil phosphates more available. It can probably be eckoned that for a dressing of 20–30 tons of dung per acre, the phosphate lressing could be reduced by up to 4 cwt as superphosphate (see page 15). Nevertheless it may still be advisable to give a light dressing of readily soluble hosphate on the seedbed to help seedlings in the early stages when establishnent is so vital.

Only the phosphates of potassium, sodium, and ammonium and certain hosphates of calcium and magnesium are soluble in water. On the whole he chief sources of soluble phosphate in the soil solution are phosphates of alcium.

The pH of the soil has a great influence on the type of phosphate into vhich the fertilizer is converted after application, and the forms which plants an take up most readily are favoured by slightly acid soils with a pH between ·0 and 6·5. Chalky and limestone soils with a pH of above 7·0 convert the hosphate into other less available forms; in very acid soils, with a pH below ·5, insoluble iron and aluminium phosphates are formed which are of little se to plants. This partly explains the value of keeping the soil at a very lightly acid level, and of liming soils that are still more acid.

When a soluble phosphate fertilizer, such as superphosphate, is added to soil, it must be gradually converted to a less soluble or even insoluble form. For a time, however, part of the phosphate is likely to remain soluble, for the articles of fertilizer interact slowly with the soil around them. In these ockets, roots find a ready source of soluble phosphate. As the fertilizer ecomes more completely mixed and spread throughout the soil by subequent cultivations its conversion to less soluble forms is hastened. This xplains the need to apply soluble phosphatic fertilizers shortly before sowing, nd the falling off in their effect with time.

When an insoluble phosphate, such as a bone phosphate, is applied to a oil it slowly becomes soluble, but not at a sufficiently rapid rate for crops own or planted immediately afterwards unless the soil is acid and moist.

This explains the need for relatively large dressings of these phosphates and their comparative ineffectiveness on chalky soils in the drier parts of the country. Continuous use of the bone phosphates does in time appear to raise the level of available phosphate in the soil, and as they are usually applied at heavy rates the effect is often considerable. It must not be overlooked, however, that the immediate effect of these fertilizers is probably due to the nitrogen they contain. The nitrogen in an application of 5 cwt bone-meal, for example, is equivalent to $\frac{1}{2}$ to $1\frac{1}{4}$ cwt sulphate of ammonia.

Much is heard of the problem of "fixation" of phosphates by the soil, and the statement has been made that not more than 25–30 per cent of added phosphate is recovered in subsequent crops. This may be true of soluble phosphates added to soils that are low or very low in available phosphate. Some of the reasons why this occurs have been given: the conversion to less soluble forms and the dispersion of the phosphate throughout the soil by subsequent ploughings and cultivations, but soluble phosphate may also be tenaciously held by clay soils from which it is only slowly released.

Fixation is therefore a greater problem on heavy soils than on light soils. Ultimately, however, with continued application of phosphates, fixation becomes less and less and the level of available phosphate rapidly rises. On many of the older market-garden soils that have been generously treated for a long time, the serious stages of phosphate fixation have long since been passed and they now contain high levels of available phosphate which can be maintained by very small applications of soluble phosphate.

Although a relatively high level of phosphate may be desirable for vegetables, too high a level results in reducing yield through hastening maturity unduly. The presence of excess phosphate may also tend to reduce the availability of some other nutrients such as potassium and magnesium. These considerations prompt a policy of moderation with market-garden soils. Many of them now contain large reserves of phosphate, especially where compound fertilizers or bone manures have long been the basis of manurial practice.

Superphosphate

Superphosphate (containing 18 per cent water-soluble P_2O_5)* is one of the most widely used phosphatic fertilizers, and is produced in both granular and powder forms. In its manufacture, finely ground phosphatic rock is mixed with sulphuric acid to produce a mixture of water-soluble calcium phosphate (25–30 per cent) and gypsum (calcium sulphate, 60 per cent). In modern methods of manufacture a little less than the theoretically required amount of sulphuric acid is used, with the result that a little insoluble phosphate remains (1–2 per cent) but the superphosphate contains no free acid. There is no evidence that the use of superphosphate increases the acidity of soil, since any loss of exchangeable calcium is made good by the fertilizer.

* Under the Fertilisers and Feeding Stuffs Act of 1926, the amount of water-soluble phosphoric acid expressed as P_2O_5 must be stated. In addition the percentage of phosphate may sometimes be given in other ways on invoices, e.g., as tricalcium phosphate or tribasic phosphate of lime ($Ca_3 P_2O_8$), or as phosphorus (P), all of which have been obtained from the figure for P_2O_5, but result in very different percentage figures. For example, 18 per cent phosphoric acid (P_2O_5) is equivalent to 39 per cent tribasic phosphate or 8 per cent phosphorus.

The phosphate is mostly soluble in water, but it is not washed out of soil. It is readily available to plants for a comparatively short time, although it may be slowly released over a period of years.

Superphosphate should be applied during the preparation of the seedbed for annual crops or as annual dressings in early spring to perennials.

Triple Superphosphate

Triple superphosphate (47 per cent water-soluble P_2O_5) is made by using orthophosphoric acid instead of sulphuric acid for converting the phosphate in the rock into a soluble form. As its name implies, it contains almost three times as much P_2O_5 as ordinary superphosphate and is therefore more economical in use; 1 cwt triple superphosphate provides the same amount of water-soluble phosphoric acid as $2\frac{1}{2}$ cwt of ordinary superphosphate. It is obtainable both in powder and granular forms.

Basic Slag

Basic slag (6–20 per cent insoluble P_2O_5) is a by-product of the steel industry and its actual composition depends on the particular steel-making process. For use as a fertilizer it is ground finely, so that at least 80 per cent will pass through a 100-mesh sieve. It does not act as quickly as superphosphate, as the phosphate in it is not soluble in water, but a variable proportion is soluble in weak acids and this is available to plants. Basic slag contains the equivalent of about two-thirds its weight of calcium carbonate. It is not widely used for vegetable crops, though it is considered useful for root crops and peas in farm rotations. A high grade, high-soluble slag should be chosen.

Consignments are classified by "grade" and "solubility". The former is a measure of the total amount of P_2O_5 it contains; the latter expresses the proportion which is soluble in 2 per cent citric acid, and hence its availability to a crop. In a "high-soluble" slag over 80 per cent of the total P_2O_5 is soluble in 2 per cent citric acid, while a percentage of less than 40 per cent solubility classes the sample as "low-soluble".*

Ground Mineral Phosphate

This is phosphate rock which has been finely ground. It contains 27–29 per cent insoluble P_2O_5, but as this is not soluble either in water or weak acid, its use on market-gardening crops is therefore not recommended.

Bone Fertilizers

Untreated bones decompose very slowly in soil, because of the fats and greases they contain. Many bone fertilizers are processed by treatment with solvents to remove grease and by high-pressure steam to remove gelatin, and are then ground for use. The phosphate is in an insoluble form which gradually becomes available to plants, depending on the fineness of grinding. Most bone fertilizers also contain a small proportion of nitrogen. The cost per unit of P_2O_5 is high (see page 51).

* Under the Fertilisers and Feeding Stuffs Act of 1926, the seller must state (*a*) the percentage of total phosphoric acid as P_2O_5, (*b*) the percentage of total P_2O_5 soluble in 2 per cent citric acid (citric solubility), and (*c*) the percentage of the material which will pass through a standard 100-mesh sieve.

Bonemeal (22 per cent insoluble P_2O_5, 2–5 per cent N) is produced by crushing degreased bones. The remaining cartilage contains a small percentage of nitrogen which is available to plants (see page 34). Its rate of action depends to some extent upon the fineness of grinding.

Steamed Bone Flour (28 per cent insoluble P_2O_5, 1 per cent N) is the residue after removal of both fats and gelatin. It contains more phosphate than bonemeal and practically no nitrogen. It is very finely ground which helps its availability. It is often used as a drier or conditioner in making compound fertilizers.

Meat-and-Bonemeal is very variable in composition, but samples containing about 7 per cent nitrogen and 16 per cent insoluble P_2O_5 are fairly common (see page 34). It is a popular manure for vegetable crops.

Dissolved Bone (7–8 per cent soluble P_2O_5, 7–8 per cent insoluble P_2O_5, 2–3 per cent N) is prepared by treating degreased, dried bones with sufficient sulphuric acid to convert half of the total phosphate into the water-soluble form as found in superphosphate.

Bone Superphosphate consists of a mixture of approximately equal proportions of superphosphate and bonemeal.

Precipitated Bone Phosphate contains 35 per cent insoluble P_2O_5, and is prepared by treating degreased bones with dilute hydrochloric acid to remove gelatin, when some of the phosphate is converted into the soluble form which is recovered by adding milk of lime to the solution. It is a fine, white powder, soluble in 2 per cent citric acid, and readily available to plants.

Other Phosphate Fertilizers

Spent bone charcoal is a by-product from sugar-refining and contains about 35–40 per cent P_2O_5 with 10 per cent carbon. Guano contains 9–11 per cent insoluble P_2O_5 and 10–15 per cent N, and is primarily of value for its nitrogen content (see page 33).

POTASH FERTILIZERS

A high level of potassium in the soil is essential for the health and productivity of many vegetable crops. Potassium and nitrogen are, in a sense, complementary to each other, and a good supply of potassium in the plant helps to offset the effects of an excess of nitrogen by giving a balanced type of growth less liable to disease. Too much potassium in the soil tends to induce magnesium deficiency in susceptible crops.

Farmyard manure contains on the average about 11 lb potash (K_2O) per ton, and applications of potassic fertilizers may be somewhat reduced when generous dressings of farmyard manure are given, say 1–2 cwt muriate for a dressing of 20–30 tons of dung (see page 15). Some potassium is returned to the soil in a readily available form when crop residues are ploughed in. In coastal districts applications of seaweed are a source of potassium.

The vast majority of the salts used as potassic fertilizers are obtained from natural deposits of mixed salts; the chief producing countries are Germany, France, U.S.A., Israel and Russia. Minor sources of potassium compounds for fertilizer use are flue dusts, kelp or seaweed ash and various by-products from the wine and sugar industries.

Sulphate of potash and the higher grades of muriate (50–60 per cent K_2O)* are suitable for inclusion in compound fertilizers, but the lower grades of potassic fertilizer tend to give hard setting mixtures and should only be mixed immediately prior to use. Potassium compounds are not readily lost from the soil in drainage water, and they may be applied to the soil well in advance of the crop.

Muriate of Potash

The potassium in this fertilizer is present as chloride. The best known grade is guaranteed to contain not less than 60 per cent potash (K_2O) and is available in powder and granular forms. Other grades contain 50 and 40 per cent potash respectively, the latter being sometimes known as potash manure. Potash manure contains about one-quarter of its weight of common salt (sodium chloride). Muriate of potash is the usual form of potash in compound fertilizers, although mixtures containing muriate have a greater tendency to set hard than those containing sulphate.

For most vegetable crops the higher grades of muriate are a satisfactory cheap form of potash. The chloride content of this fertilizer, however, may be objectionable for certain crops if repeated heavy dressings are applied and for very intensive work sulphate of potash may be preferred. Where mixed vegetable and soft fruit cropping is practised, it should be noted that muriate of potash is unsuitable for certain fruit crops (notably red currants, gooseberries and raspberries) and sulphate of potash should be used.

Sulphate of Potash

Sulphate of potash is manufactured from the chloride and hence is more expensive. It is guaranteed to contain not less than 48 per cent K_2O. Sulphate of potash is usually in good physical condition and unlike muriate it shows little tendency to pick up moisture from the atmosphere. As it does not contain chloride, it is the most suitable fertilizer for intensive work under glass.

Potash-Magnesium Sulphate Fertilizers

Two fertilizers containing both potash and magnesium sulphate are now on the British market. Sulphate of potash-magnesia (known in Holland as "Patentkali") contains about 28 per cent K_2O and 25–38 per cent magnesium sulphate and is popular for use on magnesium-deficient soils on the continent. The other fertilizer, in which potash is present as the chloride, contains 40 per cent K_2O and 15 per cent magnesium sulphate.

Potash Nitrate

A mixed nitrate of soda and potash is sold under the name of Chilean potash nitrate. The analysis varies but it usually contains 10–15 per cent K_2O and 15 per cent nitrogen. The potash and nitrogen are readily available and it is a popular top dressing for vegetable crops (see page 37).

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* Under the Fertilisers and Feeding Stuffs Act the potassium content of potassium salts and mixtures used as fertilizers must be declared in terms of the percentage of potash (K_2O). If the percentage of potassium (K) is required, the potash (K_2O) figure should be multiplied by 0·83. To convert potassium (K) to potash (K_2O), multiply by 1·21.

Nitrate of Potash

Nitrate of potash or saltpetre contains about 40 per cent K_2O and 12–14 per cent nitrogen in the nitrate form. It is too expensive for general purposes and is mainly used as a top dressing for high value crops, especially in glasshouses (see page 37).

Kainit, Potash Salts

These fertilizers contain relatively small amounts of potash (kainit 14 per cent K_2O, potash salts 20 and 30 per cent K_2O), together with common salt (sodium chloride) and magnesium and calcium compounds. They have a high common salt content and are not generally recommended for vegetable crops but occasionally they have special uses (see page 46).

Flue Dusts

This material is obtained from blast furnaces and contains a variable (usually low) percentage of potash, principally as the sulphate and the silicate. It can sometimes be a relatively cheap type of potash but it should only be bought on analysis. Flue dust sometimes contains substances injurious to plants and it is best applied well in advance of the crop.

Plant Ashes

From time to time the ashes of various plant residues, e.g., flax (shive ash) are offered for sale as a source of potash. The potash content usually ranges between 5 and 15 per cent K_2O but, like flue dusts, they should only be bought on analysis.

LIME AND LIMING

In addition to supplying the nutrient calcium, lime has other important functions in the growing of crops. In particular, it neutralizes excess soil acidity and brings about conditions in the soil suitable for the growth of crops and the activity of micro-organisms; it may play some part in improving the tilth of heavy soils.

Forms of Lime

The chief forms of lime include quicklime (calcium oxide), slaked or hydrated lime (calcium hydroxide), ground limestone or chalk (calcium carbonate) and the magnesian limestones and limes (the former is a mixture of magnesium and calcium carbonates and the latter a mixture of magnesium and calcium oxides).

Ground limestone or chalk is a satisfactory and cheap liming material and has the advantage of being easy to store and pleasant to handle. The finely ground grades are more suitable for vegetable crops than the coarser products because of greater uniformity of spreading and quicker action.

Ground burnt lime (quicklime) and hydrated lime are slightly quicker in action than ground limestone or chalk, but there is no reason to believe that they have any special virtues for vegetable crops, although hydrated lime is a long established favourite among horticulturists.

Ground magnesian limestone has special uses where magnesium deficiency occurs in vegetable crops on acid soils. It is produced in areas which

are remote from the main vegetable growing districts and transport costs may therefore be high.

As a rough guide, 2 parts of finely ground chalk or limestone are equivalent to 1½ parts of hydrated lime or 1 part of quicklime. All the main forms of lime are bought on a declared "Neutralizing Value", which is an expression of the value of the liming material for neutralizing soil acidity. For example the statement that a ground chalk has a Neutralizing Value of 53 means that 100 lb has the same effect in neutralizing acidity as 53 lb calcium oxide (CaO), say, about ½ cwt quicklime.

Importance of Liming

For general market-garden purposes a soil with a good reserve of lime is required and a pH value of 6·5 (i.e., a soil reaction just short of neutral) may be regarded as desirable. Crops differ, of course, in their ability to grow satisfactorily at various levels of acidity as will be seen from the following table, but it must be borne in mind that such a division is an arbitrary one, much depending on the soil and the rainfall. Crops will often grow reasonably well in the wetter areas at levels of acidity at which they would fail in the drier parts of the country.

Level of pH Required for Satisfactory Cropping

About pH 6·5 (need nearly neutral conditions)
Beans (runner and French), beetroot, brassicas crops (e.g., cabbage, cauliflower), carrots, celery, onions, leeks, lettuce, parsnips, rhubarb and spinach. (Note: rhubarb tolerates quite acid conditions but probably grows best when well supplied with lime.)

About pH 6·0 (satisfactory under slightly acid conditions)
Broad beans, peas, radishes, sweet corn, swedes and turnips.

About pH 5·5 (satisfactory under moderately acid conditions)
Chicory, cucumbers, marrows, potatoes and tomatoes.

In the second table pH values are given, below which crops may be expected to fail or at any rate be unsatisfactory in the eastern half of England. As already explained, however, the critical pH value will be greatly influenced by soil, rainfall, and previous manuring (especially with farmyard manure which tends to offset the effects of acidity) and crops may sometimes be found growing reasonably well at lower pH values than those given.

Level of pH below which Crops may be Unsatisfactory

pH	*Crops*
6·5	Cauliflower, spinach.
6·0	Lettuce, leeks, onions, parsnips.
5·5	Beans (runner, French and broad), peas, beetroot, brassicas, carrots and celery.
5·0	Cucumbers, marrows, potatoes, tomatoes, sweet corn, rhubarb.

Of the crops listed, cauliflower and broccoli are especially liable to fail if the soil is at all acid. On some soils, for example, cauliflower and broccoli develop a strap-like condition of the leaves known as whiptail in which the plants are often blind and fail to produce a saleable curd. This condition is usually due to a deficiency of the micro-nutrient molybdenum which has been induced by soil acidity. Such cases can frequently be prevented by an

adequate dressing of lime applied well in advance of the crop. Not all cases of whiptail are due to soil acidity and considerable investigation may be required in any specific instance to find the exact cause. Spinach is another crop which is particularly sensitive to acidity and under acid conditions plants remain stunted and yellow.

Many market-gardening areas, for obvious reasons, are situated on light soils from which the loss of lime by leaching is considerable. This loss is often aggravated by the heavy dressings of fertilizers which are given and by the removal of crops from the land. It follows, therefore, that regular attention to liming is necessary on many market garden soils. Although it is quite impossible to give a reliable general guide, once the lime status of the soil has been raised to a satisfactory level 1–2 tons per acre of chalk or ground limestone every few years should be a sufficient maintenance dressing. In order to raise the pH value to any desired level heavier dressings of lime are required on heavy soils than on light ones.

It should not be overlooked, however, that the over-liming of soils and the unnecessary liming of alkaline soils (pH over 7·0) may have just as serious consequences as under-liming, and it should not be taken for granted that liming is required. When there is any doubt concerning the need for lime, the best course is for the grower to consult the N.A.A.S. adviser for his district as to the amount of lime required (if any) for an initial dressing, and the appropriate treatment in subsequent years.

A few diseases of vegetables are affected by the lime content of the soil, of which the best known are club root of brassicas, and common scab of potato. Club root is less serious on soils well supplied with lime, but common scab is usually worse on such soils.

Certain micro-nutrient deficiencies, notably manganese and boron deficiencies, can be induced by over-liming and are likely to be a problem to the vegetable grower on some soils (see pages 26–28). Boron deficiency can also be a serious problem, more especially in dry seasons, giving rise to such conditions as canker in beetroot, brown heart in swedes and heart rot in celery.

Magnesium deficiency is sometimes a problem in vegetable crops, particularly in cauliflowers (see pages 25 and 64). On acid soils this deficiency can be controlled by dressings of ground magnesian limestone which supplies magnesium as well as correcting soil acidity.

MISCELLANEOUS FERTILIZERS

Agricultural Salt

Common salt (sodium chloride) is an old-established fertilizer for mangolds and sugar beet, and experiments have shown that its use at 3–5 cwt/acre increases the yield of these crops over a wide range of soils. It also results in small increases in yield of table beet.

It has been a long-standing practice to manure asparagus beds with common salt, but crops equally good have been obtained without it. It should be borne in mind that low-grade potassic fertilizers contain considerable amounts of salt.

Repeated dressings of salt are injurious to the structure of some soils, and care should be taken in using this material on difficult land. As salt adversely affects the stand of seedlings, it is best ploughed-in some months before

sowing. Furthermore, it is injurious to some vegetables and it would therefore be unwise to use it on market garden land until small scale trials have shown benefit from its use.

Magnesium Sulphate (Epsom Salts)

When magnesium deficiency is a problem in vegetable crops on alkaline soils, it may be controlled by working in 3–4 cwt magnesium sulphate per acre before sowing or planting the crop. Crops may also be sprayed with 2 per cent magnesium sulphate solution (20 lb magnesium sulphate per 100 gal per acre plus a wetting agent). Two or three applications at fortnightly intervals may be required. On acid soils magnesian limestone may be used since it corrects acidity as well (see page 46).

Micro-nutrients

Deficiencies of manganese, boron and molybdenum occur quite frequently in vegetable crops in this country, but iron deficiency is rare. In addition deficiencies of copper and zinc, although not yet recorded in vegetable crops here, are of importance in other parts of the world.

Manganese and boron deficiencies are usually found on naturally alkaline soils or on soils which have been made alkaline by an excessive dressing of lime. Molybdenum deficiency on the other hand is usually most severe under acid conditions and some degree of control can often be achieved by liming.

It should be borne in mind that with micro-nutrients the margin between the required dose and the toxic dose is often small, and both with sprays and soil dressings it is wise to treat a small plot before treating the whole field. Many of the micro-nutrients, as well as magnesium sulphate, may be incorporated in certain insecticidal, fungicidal and herbicidal sprays, but the advice of the manufacturers of such sprays should be sought before doing so.

Fertilizers are occasionally sold which have been "fortified" by the addition of micro-nutrients. Although these may be of value in special areas and on particular farms, their general use cannot be recommended.

Details of methods of controlling deficiencies of these elements are given in the section on micro-nutrients (see page 26), but it must be emphasized that in all suspected cases it is wise to seek technical advice.

STORAGE OF FERTILIZERS

Fertilizers should be stored in a dry barn or other building, the sacks being raised off the floor by means of boards or bales of straw. Direct contact between the sacks and the walls of the building should also be avoided. Many fertilizers, especially sulphate of ammonia, have a very corrosive action on concrete and ironwork if they are allowed to get damp. The sacks should be laid on the flat as closely together as possible but should not be stored more than six high because the weight of the overlying sacks tends to compress and harden the fertilizer in those beneath. The windows and doors of the fertilizer store should be kept closed except in drying weather.

The fertilizers noted below as forming unsuitable mixtures should not be piled together and low grade potash manure should always be stored apart from other fertilizers because of its capacity for picking up moisture.

COMPOUND FERTILIZERS AND MIXTURES

Crops differ in their requirements for nitrogen, phosphorus, potassium and other plant nutrients. Brassicas and other leafy plants, for example, need more nitrogen than root crops which in their turn need more potash than many other crops. Many vegetable growers prefer to buy ready-mixed compound fertilizers rather than to apply nitrogenous, phosphatic and potash fertilizers separately or to make up their own mixtures. A wide range of compound fertilizers is available from the various manufacturers who prepare them to meet the needs of a variety of soils and crops.

Home Mixing

Despite the wide range of compound fertilizers now available for vegetable crops, it is not always possible to buy mixtures with the exact nutrient ratio desired for a specific soil or crop. This is the main argument in favour of the practice of home mixing, or of supplementing a compound fertilizer with extra dressings of "straight" fertilizers. When the vegetable grower wishes to mix his own fertilizers the best plan is to do so just before use, although it is possible to add "conditioners" such as steamed bone flour or sawdust flour, various low grade organic manures or ground rock phosphate to improve the keeping quality and physical condition of fertilizer mixtures. Prior to mixing, any very lumpy material should first be broken down in the sacks by banging them with the flat side of a shovel. The various fertilizer constituents should then be spread on the floor in alternating thin layers. The mixture is then shovelled up into a heap and finally passed through a sieve, any lumps being broken down and in turn passed through the sieve.

Some fertilizers should not be mixed together. The more important of these undesirable mixtures are described below:

(i) Sulphate of ammonia should not be mixed with lime or any substances containing lime (e.g., basic slag, "Nitra-Shell" or "Nitro-Chalk") because of the danger of losing ammonia.

(ii) Superphosphate should not be mixed with lime or any substance containing lime because of the reversion of the water-soluble phosphate to an insoluble form.

(iii) Nitrate of soda should not be mixed with superphosphate or dissolved bones, as such mixtures quickly pick up moisture from the air and there is also some danger of losing nitrogen.

(iv) Low-grade potash manures readily pick up moisture and should only be mixed with other fertilizers immediately before use.

Fertilizer Ratio (NPK Ratio)

Under the Fertilisers and Feeding Stuffs Act, the percentages of nitrogen (N), water-soluble and insoluble phosphoric acid (P_2O_5) and potash (K_2O) must be stated. These percentages give the fertilizer ratio or NPK ratio. For example, a well-known compound fertilizer contains 7 per cent nitrogen, 7 per cent phosphoric acid and $10\frac{1}{2}$ per cent potash, and its fertilizer or NPK ratio is $7:7:10\frac{1}{2}$. Amongst the wide range of compounds made by individual manufacturers are fertilizers having NPK ratios of 12:12:18, 9:9:15 and 0:10:20. The last mentioned is a concentrated phosphate-potash compound containing no nitrogen.

MIXING FERTILIZERS

(blank square)	MAY BE MIXED
X	MAY BE MIXED IF APPLIED SOON AFTER
X	DO NOT MIX

			NITROGEN				POTASH		PHOSPHATE				LIME	
			1	2	3	4	5	6	7	8	9	10	11	12
			SULPHATE OF AMMONIA	"NITRA-SHELL", "NITRO-CHALK"	NITRATE OF SODA	CALCIUM CYANAMIDE	SULPHATE OR MURIATE OF POTASH	POTASH SALTS, KAINIT	SUPERPHOSPHATE	BASIC SLAG	BONE AND ROCK PHOSPHATE	AMMONIUM PHOSPHATE	CARBONATE OF LIME OR MAGNESIA	OXIDE OF LIME OR MAGNESIA
NITROGEN	1	SULPHATE OF AMMONIA				**X**		X		**X**			X	**X**
	2	"NITRA-SHELL", "NITRO-CHALK"				**X**		X	X	**X**		X		**X**
	3	NITRATE OF SODA						X	X			X		
	4	CALCIUM CYANAMIDE	**X**	**X**				X	**X**			**X**		
POTASH	5	SULPHATE OR MURIATE OF POTASH						X						
	6	POTASH SALTS, KAINIT	X	X	X	X	X		X	X	X	X	X	X
PHOSPHATE	7	SUPERPHOSPHATE		X	X	**X**		X		**X**	X		X	**X**
	8	BASIC SLAG	**X**	**X**				X	**X**			**X**		
	9	BONE AND ROCK PHOSPHATE						X	X			X		
	10	AMMONIUM PHOSPHATE		X	X	**X**		X		**X**	X		X	**X**
LIME	11	CARBONATE OF LIME OR MAGNESIA	X					X	X			X		
	12	OXIDE OF LIME OR MAGNESIA	**X**	**X**				X	**X**			**X**		

Plant Food Ratio (PF Ratio)

The plant food ratio (PF ratio) is calculated from the NPK ratio by dividing each of the figures by the percentage of nitrogen or if the compound fertilizer does not contain nitrogen by the percentage of phosphoric acid. Thus the compound fertilizer with an NPK ratio of 7:7:10½ has a plant food ratio of 1:1:1½ (i.e., the NPK ratio divided by 7). The compound with an NPK ratio of 0:10:20 has a PF ratio of 0:1:2 (i.e., the NPK ratio divided by 10).

Use of the Ratios

The PF ratio is a useful way of considering the general suitability of a compound for a particular crop or soil, but it gives no information about the amount to be applied per acre. Thus two compounds having ratios of 12:12:18 and 7:7:10½ have the same plant food ratio (1:1:1½) but a smaller dressing of the first compound than of the second would be required to provide any given quantity of plant foods per acre.

As an example of the practical use of the PF ratio, we can take the case of a grower wanting a compound fertilizer with a particular NPK ratio but finding it is out of stock at the time. Suppose a compound A of analysis 7:7:10½ is required but is not available, and two other ones, B (9:9:15) and C (8:6:10½), are offered instead by the merchant. By working out and

comparing the plant food ratios (see table), it will be seen that compound B is a closer match for the required material than compound C, but it contains more potash than A, whereas C is relatively poorer in both phosphate and potash.

	NPK ratio	*PF ratio*
Compound A	7:7:10½	1:1:1½
Compound B	9:9:15	1:1:1⅝
Compound C	8:6:10½	1:¾:1¼

As a further example of the use of the ratios, a compound fertilizer may be required for manuring cauliflower. A suitable dressing per acre of "straight" fertilizers might be as follows:

4 cwt sulphate of ammonia (20·6 per cent N)
4 cwt superphosphate (18 per cent P_2O_5)
2 cwt muriate of potash (60 per cent K_2O)

The NPK and PF ratios of such a dressing are as follows:

Fertilizer	*Analysis*	*lb of nutrient per cwt*	*cwt of fertilizer per acre*	*lb of nutrient per acre*	*NPK ratio (approx.)*	*PF ratio (approx.)*
Sulphate of ammonia	20·6 per cent N	23	4	92	9	1
Superphosphate	18 „ „ P_2O_5	20	4	80	8	1
Muriate of potash	60 „ „ K_2O	67	2	134	13	1½

In this case the PF ratio is nearly the same as that of compound fertilizer A above and it only remains to work out the dressing required per acre.

Fertilizer or compound	*Plant nutrients (lb)* *N*	*P_2O_5*	*K_2O*
"Straight" fertilizers	92	80	134
1 cwt 7:7:10½ gives lb (approx.)	8	8	12
11 cwt gives lb	88	88	132

Eleven cwt per acre of this compound would, therefore, give practically the same amounts of N, P_2O_5 and K_2O as the "straight" fertilizers.

VALUATION OF FERTILIZERS

It is very desirable to be able to compare the relative prices of the same plant nutrient in different "straight" fertilizers, and also to be able to compare the costs of different compound fertilizers or fertilizer mixtures. The comparisons are made by obtaining the *unit price* of each nutrient concerned — nitrogen (N), water-soluble phosphoric acid (P_2O_5) or potash (K_2O). The unit price of a plant nutrient is obtained by dividing the cost per ton of the fertilizer by the percentage content of the plant nutrient in the fertilizer.

For example, a sample of sulphate of potash containing 48 per cent of potash (K_2O) costs £22 delivered. The *unit price* of potash is therefore $\frac{\text{cost per ton}}{\text{percentage content of } K_2O}$, i.e., £22 divided by 48 = 9*s.* 2*d.* or say 9*s.* In working out the unit price, the cost of the fertilizer should include cost of delivery to the holding, or better still the further cost of spreading on the land. One obvious reason for including these charges is that low-grade fertilizers and bulky manures may in the long run prove quite expensive in supplying plant nutrients when heavy haulage and spreading costs are involved.

The accompanying table sets out some unit prices for a number of fertilizers, all calculated on the basis of the full cost of the fertilizer (in 1959)

before any allowance for subsidy. These figures serve to illustrate the point that the unit price of a nutrient may vary widely from one fertilizer to another, especially as between organic and inorganic forms of nitrogen.

It will be understood that the figures given in the table are of no direct use to a prospective buyer, because unit price of nutrient must always be calculated on the actual cost to the buyer of the fertilizer offered. The grower should therefore work out for himself the unit price from the cost per ton of fertilizer, using the formula

$$\text{Unit price of nutrient} = \frac{\text{cost of fertilizer per ton}}{\text{percentage content of nutrient}}$$

*Unit Price for Fertilizers containing one Plant Nutrient**

Fertilizer	Price per Ton	Usual Analysis				Unit Price (to nearest sixpence)			
		N	Sol. P_2O_5	Insol. P_2O_5	K_2O	N	Sol. P_2O_5	Insol. P_2O_5	K_2O
		per cent	per cent	per cent	per cent				
Inorganic									
Sulphate of ammonia	£21. 8s.	20·8				20s. 6d.			
"Nitro-Chalk"	£18.10s.	15·5				24s. 0d.			
"Nitra-Shell"	£24. 8s.	20·5				24s. 0d.			
Nitrate of soda	£27. 5s.	16				34s. 0d.			
Superphosphate	£14. 8s.		18				16s. 0d.		
Muriate of potash	£20. 9s.				60				7s. 0d.
Sulphate of potash	£21. 1s.				50				8s. 6d.
Organic									
Hoof-and-horn	£42.10s.	13				65s. 6d.			
Dried blood	£62. 0s.	13				95s. 6d.			
Steamed bone flour	£27. 0s.			27·5				20s. 0d.	

* No account has been taken of any subsidy.

When the comparative cost of a compound fertilizer is being considered, use can be made of the unit price of the nutrients as obtained from the cost of the equivalent "straight" fertilizers. When the unit price of each nutrient has been worked out in this way, the comparative cost of the compound can be obtained as in the following example.

A compound fertilizer contains 7 per cent nitrogen (N), 7 per cent water-soluble phosphoric acid (P_2O_5), and 10½ per cent potash (K_2O). It is desired to compare its cost with that of equivalent straight fertilizers. In this example, the unit prices of nutrients given in the table above will be used, but the grower would use the unit prices he obtained himself from the cost of straight fertilizers, as described above. The equivalent straight fertilizers are assumed to be sulphate of ammonia (for N), superphosphate (for P_2O_5) and muriate of potash (for K_2O).

No. and unit price	*Value per ton* £	s.	d.
7 units of nitrogen at 20s. 6d. per unit	7	3	6
7 units of water-soluble phosphoric acid at 16s. 0d. per unit	5	12	0
10½ units of potash at 7s. 0d. per unit	3	13	6
	16	9	0

To the figure thus obtained (e.g., £16. 9s. 0d. in the example given) a reasonable amount should be added to cover the cost of mixing, bagging and other overhead expenses.

Care must be taken in applying the unit price system to compound fertilizers intended for intensively grown crops, when the fertilizers contain nutrients of organic origin that are considered of special value for particular crops. For example, where organic forms of nitrogen are considered to be of special value, then organic nitrogen must obviously be valued at a higher unit price than that for sulphate of ammonia or "Nitro-Chalk". The same principle applies to some expensive inorganic fertilizers, where these are considered to be of special use.

It should also be remembered that potash nitrate and some of the organic fertilizers contain more than one plant nutrient; in these the unit price of each nutrient has to be taken into account in assessing the relative value of different compounds. A basis of comparison somewhat on the lines of that suggested for compound fertilizers would be suitable.

Manurial recommendations are occasionally given in the form of cwt per acre of N, P_2O_5 and K_2O and these can be converted approximately to cwt of fertilizer using the following factors.

1 cwt N is equivalent to
- 5 cwt sulphate of ammonia or "Nitro-Chalk" (21 per cent) or "Nitra-Shell" (20·5 per cent)
- 6 cwt nitrate of soda
- 6 cwt "Nitro-Chalk" (15·5 per cent)

1 cwt P_2O_5 is equivalent to
- 5½ cwt superphosphate (18 per cent)
- 2 cwt triple superphosphate (47 per cent)

1 cwt K_2O is equivalent to
- 1¾ cwt muriate of potash (60 per cent)
- 2 cwt muriate of potash (50 per cent)
- 2 cwt sulphate of potash

1 cwt CaO is equivalent to
- 1 cwt ground lime
- 1¼ cwt hydrated lime
- 1¾ cwt ground chalk or limestone (carbonate of lime)

Manuring Commercial Vegetable Crops

THE purpose of this section is to give general guidance on manurial practice with vegetable crops. It has to be recognized, however, that at present there is insufficient direct experimental evidence available in this country as a basis for guidance in the practice of vegetable manuring. It is therefore proposed to give a broad picture of what is actually being done in the successful practice of vegetable production as being the best available guide at present. Nevertheless, recently established research and experimental organizations dealing with vegetables may be expected in due course to provide a solid experimental foundation on which to base manurial practice.

Vegetable crops may be considered in two groups: (*a*) those which may be grown in farming rotations, where the land is not specially prepared for vegetable culture but is in good heart; and (*b*) those which require special

conditions of culture, including a high level of soil fertility and special manurial treatment.

Cropping in the farm rotation is generally confined to early potatoes, autumn and winter brassicas (such as Brussels sprouts, savoys, winter cabbage and broccoli), swedes, maincrop carrots and peas. The manurial treatment required for these crops in farming rotations is relatively simple provided an adequate supply of farmyard manure is available.

BUILDING UP SOIL FERTILITY

The level of fertility required for the intensive production of vegetable crops is much higher than is necessary in ordinary farming practice. A soil built up for intensive vegetable growing has been artificially made by manurial and other means and must be maintained by similar means.

In choosing a soil for vegetable growing, the following considerations are important:

1. There should be a sufficient depth of soil and no underlying "pan".
2. There should be a good moisture supply, but drainage should not be defective.
3. There should be an adequate supply of organic matter.
4. The soil should be very slightly acid (pH say about 6·5).
5. Potash and phosphate should be present in adequate amounts.

Whilst new land for vegetable crops is being developed and soil fertility is being raised to the desired level for intensive cropping, the most suitable crops to grow include early potatoes, brassicas (excluding cauliflower and early greens), parsnips, peas and broad beans. In building up fertility, attention should be given to the need for organic matter, appropriate fertilizer treatment, and liming if too acid, but little can be done to alter over-alkaline soils.

Organic Matter for Intensive Cropping

The problem of building up and maintaining organic matter in the soil is a difficult one under present conditions, but it has to be solved if intensive cropping is followed. Organic matter is necessary to ensure a good tilth and satisfactory water conditions in the soil, to provide a storehouse for plant nutrients and serve as a safeguard against adverse weather conditions.

Where grassland is broken up for cropping, the ploughing-in of the turf provides a temporary solution of the problem of organic matter supply, but the control of wireworms and the difficulty of obtaining a firm seedbed may present problems. When the cropping system permits, the alternation of vegetable crops with leys can provide a longer term solution of the problem, and is worth considering seriously.

Where arable land is taken for intensive vegetable cropping, some kind of bulky organic material should be applied. When farmyard manure is not available, other local materials should be sought, such as straw composts, mushroom manure, seaweed, sewage sludge, town refuse. Green manuring including heavy seedings of quick-growing grasses (e.g., 40 lb Italian ryegrass per acre) for a period of 6 months or so offer other methods of providing root fibre for organic matter and tilth improvement. The vegetable grower should not overlook the value of trimmings and waste from his own crops,

which provide useful organic matter either composted or ploughed-in; direct ploughing-in has the advantage of ensuring that the minerals contained in the refuse are not removed from the soil and are soon available for the next crop.

Organic By-products

Particulars are also given on pages 15–21 of other bulky organic materials such as shoddy as sources of organic matter for the soil. It may be pointed out here that certain organic manures, such as hoof-and-horn and meat-and-bonemeal are not applied in sufficient quantities, nor are they suitable forms, to be of value as humus-making materials. They should be judged on their merits as organic sources of plant nutrients especially nitrogen. They have the advantage, if of suitable analysis and grist, of supplying their nutrients steadily over a long period during the growing season (see page 32).

Lime Content and Liming

Lime is also a basic factor in soil fertility. Losses of lime from soils under intensive vegetable production may be considerable, and some old market garden soils may become very acid if liming is neglected.

Before deciding on a liming policy, it is advisable to have the soil tested for acidity and lime requirement. It is not sufficient merely to apply a heavy dressing of lime as a supposed "safety measure", since this may not only be wasteful but even harmful (see page 46). Where soils are acid, the amount of the initial basic dressing is best based on soil analysis. Thereafter, maintenance dressings of ground limestone or chalk should follow at intervals of from 3 to 5 years according to the need.

Nitrogen, Phosphate and Potash

In building up and maintaining a fertility level suitable for vegetable production, adequate supplies of nitrogen, phosphate and potash are important. A high content of organic matter in the soil often implies a fairly high level of soil nitrogen, and the special needs of various crops can be met by adding the appropriate fertilizers.

With land newly brought into vegetable growing, soil analysis will help in regard to possible manurial requirements or deficiencies, and form the basis of a rational scheme of manurial treatment. With new land, special attention to phosphate and potash may be necessary, as these nutrients are often below the level needed for intensive production. Potash, in particular, is important in the manuring of vegetables, and a deficiency of this material may cause serious failures in market-garden crops. Phosphate deficiency is most likely to occur where poor grassland is broken up for vegetable culture and should be rare where good arable land is utilized.

Superphosphate is a most suitable form of phosphate fertilizer for vegetable crops, and since phosphate is principally needed in the early stages it is most effective when applied before sowing or planting out. On the other hand it should be noted that many old market-garden soils contain large reserves of phosphates, and in these instances economies in dressings can be effected with advantage.

Muriate of potash is often considered by growers to be inferior to sulphate of potash but at the present time the main potash fertilizer is the 60 per cent

nuriate, which is generally satisfactory for vegetables, except with very ntensive conditions under glass.

In long established market gardens, excess, or more rarely deficiency, of ne of other of the major nutrients may occur. Overmanuring and unbalanced manuring both lead to difficulties in crop production, which soil nalysis or visual symptoms in the crop may help to detect and to clear up.

Manuring and Quality

The increasing scarcity and high price of organic manures has raised the uestion as to how far they are necessary or economically practicable. What nay be said is that satisfactory yields of good quality vegetables are being roduced with the use of either organic manures or inorganic fertilizers, rovided crop management is good, soil fertility is maintained, and manurial lressings closely related to the needs of the particular crop and soil.

This raises the question of the effect of manuring on quality as well as on ields of vegetables. Such points as crispness and palatability, travelling ualities and other market requirements may all be affected by manuring. n the opinion of a good many practical men good quality is considered asier to achieve in the leafy crops with the use of organic forms of nitrogen ather than with artificials. But there are plenty of exceptions, especially on ertile soils in which the humus content has been maintained either naturally r by the addition of bulky manures. The importance of adequate potash can lso be stressed particularly with winter leafy crops, or with the soft type of rowth induced by mild climatic conditions. Potash promotes the hard, well-coloured type of product that travels well to market, and retains good ondition. Earliness and winter hardiness may also be improved by appropriately balanced manuring. With unbalanced nitrogen, crops may be more iable to disease and winter killing.

FERTILIZER PLACEMENT

Placing the fertilizer in some definite position close to the seed has several dvantages. Even with a light rate of application the young plant roots merge into a band of soil richer in available nutrients than would normally e the case with heavier broadcast dressings, thus giving the plant a better tart. This is specially marked on soils deficient in either phosphate or potash. Further it is claimed that the concentration of phosphate near the seed mproves the efficiency of phosphatic fertilizer on soils that readily fix hosphates to form compounds useless to crops. There is also a saving of abour and fertilizer.

The practice, however, has a disadvantage. Serious damage to germination can occur when fertilizer is placed too close to the seed, the risk being greatest on sandy soils in droughty conditions. Sulphate of ammonia and muriate of potash alone and in compounds are much more injurious than uperphosphate. Because combine drilling puts the seed and fertilizer more r less in contact in the soil, it is far more likely to cause damage than true lacement, where seed and fertilizer are kept apart.

Many vegetable crops are susceptible to fertilizer injury, and if placement s to be of value to such crops the seed and fertilizer should be laid down in eparate bands in the soil, for example, by the use of a special drill with

separate seed and fertilizer coulters which can place the fertilizer in a band about 1 in. below the level of the seed and 2 in. to the side.

Under the comparatively less fertile conditions often found in extensive vegetable production, crops may respond better to a complete fertilizer placed in a side band 2 in. away from the seed and 1 in. deeper, than to twice the amount of fertilizer broadcast. Carrots, however, do not seem to benefit from placed fertilizer and may do better when it is broadcast.

Potatoes

For many years potato growers have been accustomed to sowing fertilizer over the furrows before planting, so that it surrounds the tubers when the ridges are split back and thus is available close to the developing roots. Broadcasting of fertilizer over the baulks is more efficient than broadcasting on the flat before the baulks are drawn. Machine placement of fertilizer at the same time as machine planting of the potatoes is as effective as broadcasting over the baulks. When baulks are drawn under drying conditions, however, loss of moisture may result in a lower yield from broadcasting than from machine placement. Loss of moisture can also be avoided by broadcasting on the flat before machine planting, which has been found to be as effective as placement with machine planting.

Heavy dressings of placed fertilizers are more likely to come in contact with the seed tubers, and to cause injury. Sprout injury is likely to occur in these circumstances especially in dry seedbeds.

Beans and Peas

With these crops placement drilling is generally ineffective on fertile soils. On the other hand on soils relatively low in phosphate and potash, placement drilling of 3 cwt/acre of PK fertilizer, usually 0:10:20 in a band 2 in. to the side of the seed and 3 in. below the soil surface, has increased yield more than an equal quantity of fertilizer broadcast. On poor soils, or for early sowings when the soil is still cold, a low N-NPK fertilizer has proved useful in practice.

IRRIGATION AND MANURING*

The now widespread practice of irrigation gives rise to soil management and manurial problems which are both physical and chemical in nature. The application of large amounts of water in a matter of a few hours tends to result in the formation of a solid crust on the surface of the soil which excludes air and may be harmful to plant growth. This effect is particularly serious if the water is applied in the form of large drops to an unprotected surface. A good supply of organic matter in the soil (see pages 14–21) will help to prevent loss of soil structure following irrigation, and if the water is applied in coarse drops, care should be taken not to irrigate except when there is a good leaf cover protecting the soil surface.

From the manurial point of view, irrigation usually means that more crops and heavier crops are taken from any particular area of ground so that manuring has, generally speaking, to be increased accordingly.

Fertilizers are occasionally added to irrigation water and several types of apparatus are available for this purpose, varying from injection to metering

* See Bulletin No. 138: *Irrigation* for fuller information.

systems operated from the irrigation water as it flows through the mains. Machines can be installed centrally in the pump house or alternatively the nutrient equipment can be inserted in the particular irrigation pipes supplying the fertilizer.

Potassium nitrate is the only material in common use at the present time and is applied at rates up to 100 lb/acre per inch of water (22,622 gal). It is possible that in the future other materials such as urea may be applied via the irrigation water to improve the appearance of a crop before marketing. Some micro-nutrients can also be applied with irrigation water when they are needed to correct specific deficiencies.

Before fertilizers are added to irrigation water, the possible risk of damage by corrosion of the equipment should be realized. Metal surfaces are corroded by the salts present in fertilizer solutions, particularly by ammonium and other acid salts. Zinc galvanized tanks and piping are rapidly corroded by ammonium salts and need protecting by covering *completely* with a suitable bitumen or plastic paint. Where a change in the kind of metal occurs in an irrigation system, corrosion can start with most fertilizer salts but urea solutions not containing other fertilizers should be safe to use. Metal piping is best replaced by a suitable plastic piping. If concrete tanks are used instead of metal tanks, the concrete surface will need protection against chemical interaction with fertilizers by covering with bitumen.

POINTS IN MANURIAL PRACTICE

In the following section on the practical manuring of vegetables, guidance is given as to the needs of the various crops, including alternative suggestions for organic and inorganic manuring. It should, however, be recognized that no method or manuring programme can be regarded as being unquestionably correct, and all that can be done in the absence of experimental evidence is to attempt to indicate practices which are used widely and successfully at the present time.

The correct rates of application should also depend on the climate in different parts of the country, as well as on soil conditions and levels of fertility from previous cropping and manuring. Where there is great variation in soil type, manuring by rule of thumb is risky, and the grower should try to find out by trial what fertilizer treatments suit best. Manuring should be related to experience of the particular fields and to observation of the crop's response to the dressings applied.

Enquiry into practice in different parts of the country shows striking differences even in the same area and on the same soil, many of these differences having no obvious connection with crop or soil needs. There are of course some trends in particular regions, such as the more generous use of farmyard manure in areas where it is plentiful, as in a milk-producing county like Cheshire. On the other hand there is greater dependence on other forms of fertilizer in the arable districts of East Anglia.

Most frequently, the major problems are the scarcity of humus-making materials and the high price of all organic manures. This is leading to an increasing dependence on inorganic fertilizers. A combination of moderate dressings of bulky organic manure and appropriate amounts of inorganic fertilizers generally gives very satisfactory results and helps to make full use of a scarce commodity.

Some of the organic manures, such as hoof-and-horn, are now so dear that dressings should be matched as closely as possible to the needs of the crop, and only used on crops that really need them. Unnecessarily heavy dressings increase costs, but may not improve yield or quality, and the residues may promote an aftermath of weed growth when the crop has been cleared.

Another point often noticed in manurial practice is the indiscriminate use of the same fertilizer mixture for many different crops. Omnibus dressings sometimes waste fertilizer unnecessarily or fail to satisfy the needs of the particular crop. Nevertheless, the convenience and ease of management that growers find in using one general compound fertilizer as a basis for manuring their vegetables cannot be denied.

Quite apart from the problems posed by the results of soil analysis, it is not always easy to find a general purpose compound that is perfectly suited to the climatic or soil conditions, or to the particular crop requirements. "Bag manures" for instance may prove an expensive way of giving sulphate of ammonia to a brassica crop, or of potash or phosphate to a pea or bean crop. A reasonable compromise for most crops may be arrived at by using a standard balanced fertilizer and supplementing it with extra nitrogen, potash or maybe phosphate according to the specific needs of the crop or field concerned.

Another practice, noticeable in high farming districts and in the production of extra early or high yielding crops, is the use of very heavy dressings of soluble fertilizers. These extra heavy dressings are only justified if they bring a commensurate return. When fertilizer costs are rising, uncertainties of returns in some of these cases may well prompt an overhaul of fertilizer policy. Likewise, continual annual dressings of phosphate and potash without regard to crop or soil requirements may be both throwing money away and building up soil problems (see page 22).

Information on the reserves of plant nutrients in the soil should be taken into account. The value of soil analysis for lime, potash and phosphate requirements is well known. The detection and treatment of special micronutrient deficiencies should be regarded as matters for the expert, and the local horticultural advisory officer or advisory chemist, N.A.A.S., should be consulted when such deficiencies are suspected.

In view of the long continued policy on some established holdings of giving generous dressings of general fertilizers, regardless of the soil status in respect of potash and phosphate, the general trend in these pages will be to advocate moderate dressings of these nutrients. In some parts of the country, there is a tendency to be more generous with nitrogen than has been customary, but it is very necessary to keep potash in proportion. A useful guide is approximate equality between nitrogen (as N) and potash (as K_2O). It is left to the individual grower to experiment for himself on this basis, and to judge from his crop responses and yields whether a higher or lower level of manuring is more appropriate to his conditions. Only a critical eye and a readiness to change manurial practice in the light of evidence, whether of soil analysis or crop response, will yield the most satisfactory results.

Soil Conditions and Manuring

The practical manuring of the individual vegetable crops is discussed in the following pages, recommendations being given for two broad sets of conditions.

Moderately Fertile Soils

These soils are typical of good farmland used in rotation for vegetable growing and land in process of development for market gardening. On analysis they often reveal "medium" levels of "available" phosphate and potash. If soils are "low" or "very low" in phosphate or potash, supplementary dressings of phosphatic and potash fertilizers should be given in addition to those already included in the recommendation for moderately fertile soils in the following sections. These extra dressings need to be thoroughly incorporated in the soil to depth, and therefore should be worked in deeply either by cultivation or shallow ploughing well in advance of cropping. Such dressings may range from 3–6 cwt superphosphate and 2–4 cwt muriate of potash per acre depending upon the degree of deficiency.

Highly Fertile Soils

These soils are typical of long established market-garden land where generous manuring has been practised. They often reveal "high" or "very high" levels of available phosphate and potash on analysis.

Other Factors in Fertility

It should be recognized that the above definitions of moderately and highly fertile soils are necessarily rather limited in scope, and what constitutes soil fertility in a particular soil may well depend on other important factors that it is impracticable to take into account here. For example, no account has been taken of such factors as soil depth and drainage, moisture supply and the amount of organic matter present. A good supply of organic matter capable of active decomposition is of special importance because of its effects on soil structure and on moisture and nitrogen supply. There are certain deep soils with good water supply that are highly fertile, as judged by crop growth, even though levels of available phosphate or potash may not be particularly high.

It is difficult to be precise about the dressings of nitrogen required. Sandy soils have poor reserves of nitrogen unless heavy dressings of bulky organic manures, such as farmyard manure, have been applied over a period of years, whereas some organic soils have a substantial natural reserve of nitrogen. The quantities of nitrogen recommended for a particular crop must be adjusted, therefore, in the light of experience with any given soil.

Unless otherwise stated, dressings of farmyard manure should be ploughed in well in advance of cropping and fertilizers worked in during the cultivations before sowing or planting.

Use of Compound Fertilizers

Quantity Required

In the sections which follow, the recommendations regarding individual crops are given for "straight" fertilizers and for compound fertilizers as alternatives, compound fertilizers being described by means of their Plant Food Ratios. The meaning of the term Plant Food Ratio is described on page 49, but briefly it is the ratio of the percentages of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) in the compound fertilizer. Thus the ratio of N to P_2O_5 to K_2O in a fertilizer containing 7 per cent N, 7 per cent P_2O_5 and $10\frac{1}{2}$ per cent K_2O is $1:1:1\frac{1}{2}$ and this is its Plant Food Ratio. A fertilizer containing 10 per cent P_2O_5 and 20 per cent K_2O (i.e., no nitrogen) would have a Plant Food Ratio of 0:1:2.

If in following the recommendations given for the individual crop, it is decided to use a compound fertilizer, it is first necessary to choose one as near as possible to the Plant Food Ratio suggested, and then decide at what rate per acre it should be applied. An example will make this clear.

Example:

Compound fertilizer A (7 per cent N, 7 per cent P_2O_5, 10½ per cent K_2O)
Compound fertilizer B (12 per cent N, 12 per cent P_2O_5, 18 per cent K_2O)

It is desired to supply 70 lb N per acre by means of A or B. Both A and B have the same Plant Food Ratio of 1:1:1½, and either could be chosen, but B is obviously more concentrated than A.

A simple, if rough, method of estimating how much fertilizer is required is as follows: Divide the "pounds N per acre" (i.e., 70) by the percentage of nitrogen in the fertilizer:

Fertilizer A (7 per cent N) $\frac{70}{7} = 10$ cwt per acre

Fertilizer B (12 per cent N) $\frac{70}{12} = 6$ cwt per acre

Meaning of "Parts per Acre"

In this method, however, a hundredweight is taken as 100 lb and the nitrogen content in A and B as 7 lb and 12 lb per cwt respectively, whereas in fact a hundredweight is 112 lb and the nitrogen content about 8 lb and 13½ lb respectively.

The use of this method, therefore, results in rather too high an estimate of the quantity of compound required. Although in practice such estimates are generally near enough to be recommended rates for most practical purposes, it can be confusing to those who are accustomed to working with more exact figures of lb per cwt and per acre.

To overcome this, and to provide a simple method of estimating quantities as so many cwt per acre of a compound fertilizer, the amounts of the particular nutrients required have been adjusted accordingly, and stated as "parts" per acre instead of pounds per acre.*

The quantity in cwt per acre of the chosen compound is simply obtained by dividing the stated number of parts per acre by the percentage content of the given nutrient. In the example already given, 60 parts N per acre are required and the quantity of compound per acre would be as follows:

Fertilizer A (7 per cent N) $\frac{60}{7} = 8\frac{1}{2}$ cwt per acre

Fertilizer B (12 per cent N) $\frac{60}{12} = 5$ cwt per acre

As A and B have the same Plant Food Ratio, the quantity of phosphate and potash supplied by 8½ cwt and 5 cwt respectively of these two compounds will be about the same per acre.

If anyone finds it difficult to follow the use of the word "part" in this particular way, he will not be far off the mark if he calls a "part" a pound; provided he sticks to the method given for working out the quantity of compound required per acre and does not mind occasionally being a hundredweight or two out per ton of fertilizer. Those on the other hand who want to

* 100 parts = 112 pounds. *Example:* 70 lb N per acre $= \frac{70 \times 100}{112} = 62$ parts N per acre (say 60 parts, in round figures).

be able to convert percentage content of nutrient into pounds or hundredweights per acre simply and accurately have the means of doing so.

Choice of Compound

Where a range of Plant Food Ratios is quoted in the following sections, any compound within the range should prove reasonably satisfactory, e.g., given a Plant Food Ratio range of 1:2:2½:2–2½, a compound with a ratio of 1:2:2 or one of 1:2½:2½ might be equally well chosen.

As it would not be practicable for a grower producing a number of vegetable crops to keep a large range of compound fertilizers in stock, only Plant Food Ratios that are commonly available* are mentioned in the following pages. For this reason some of the compound fertilizers suggested will not always supply quite the same amounts of plant foods as the alternative "straight" fertilizers. For example, the fertilizers recommended for celery on highly fertile soils are 3 cwt sulphate of ammonia, 2 cwt superphosphate and 2 cwt muriate of potash per acre *or* a compound fertilizer of Plant Food Ratio 1:1:1½–1⅔ to supply 60 parts (i.e., about 70 lb) nitrogen per acre. In this example the "straight" fertilizers would provide 69 lb nitrogen (N), 40 lb phosphoric acid (P_2O_5) and 134 lb potash (K_2O) and the compound fertilizer 70 lb N, 70 lb P_2O_5 and 105–117 lb K_2O. Thus the compound fertilizer provides too much phosphoric acid and too little potash relative to the "straight" fertilizers.

Where crops such as peas, early potatoes, broccoli, carrots, etc., are grown on a large scale it would be worth while to obtain a special compound fertilizer which would more nearly provide the plant nutrients required and suit the soil conditions better than the compound fertilizer suggested in the following section.

Summing up, it should be repeated that in assessing soil fertility and the fertilizer needs of crops much must depend on local conditions and on local knowledge and experience of crop responses. The recommendations in the following sections, although based on a large body of collective experience from all parts of the country, are best regarded as no more than general guides to the kind and level of manuring likely to be needed for the various vegetable crops under the given soil conditions.

RECOMMENDATIONS FOR PARTICULAR VEGETABLE CROPS

NOTE (A). QUANTITY PER ACRE: In the following sections, *quantities* of manures, fertilizers or plant nutrients are given *per acre*.

NOTE (B). PARTS INSTEAD OF POUNDS: As already explained, to simplify the calculation of the quantity per acre of a compound fertilizer required to supply a given amount of plant nutrient, a hundredweight is reckoned as 100 (instead of 112) and the amount of nutrients is then expressed in "parts per acre" instead of "lb per acre", the figures being scaled down accordingly.

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* The Plant Food Ratios used in the detailed recommendations are as follows:

1:1:1	1:1:1½–1⅔
0:1:1	1:2–2½:2–2½
0:1:2	1⅓–1½:1:1

In addition, two special ones are mentioned:

1–1½:1:3 (for winter cauliflowers, carrots on fen peats and self-blanching celery)
1:4:4 (for swedes).

For example, in the foregoing recommendation for celery, the nitrogen required per acre is stated as "3 cwt sulphate of ammonia *or* a compound fertilizer ($1:1:1\frac{1}{2}-1\frac{2}{3}$) to supply 60 parts* nitrogen".

The quantity of the chosen compound fertilizer (e.g., one containing 12 per cent N, 12 per cent P_2O_5, 18 per cent K_2O) is obtained by simply dividing parts per acre (60 parts) by the percentage of the given nutrient (12 per cent N). Therefore the quantity required will be $60 \div 12 = 5$ cwt per acre of this compound, and this will supply about the same amount of nitrogen as 3 cwt sulphate of ammonia.

NOTE (c). "NITRA-SHELL" AND "NITRO-CHALK". Where "Nitro-Chalk" is referred to in the text, it should be taken to apply equally to "Nitra-Shell". The quantities recommended in the following pages are based on 20–21 per cent "Nitra-Shell" or "Nitro-Chalk".

BRASSICA CROPS

Brussels Sprouts

Although a fairly heavy but well-drained soil is probably ideal for this crop, it can be grown successfully under a wide range of soil conditions provided the extremes are avoided. Good drainage is very important, more especially for the later crops, as the plants are easily damaged by wetness.

Manuring should be generous but high rates of nitrogen will need to be accompanied by high rates of potash. Heavy dressings of farmyard manure are not used as much as formerly; they may tend to make some soils too loose or puffy, and therefore prone to produce "blowers". One or more top dressings of sulphate of ammonia or "Nitro-Chalk" are needed during the growing season, and in the drier parts of the country they may be given as late as just before the first pick.

Moderately Fertile Soils	3–4 cwt Sulphate of ammonia
	3–4 cwt Superphosphate
	3 cwt Muriate of potash
Compound fertilizer:	$1:1:1\frac{1}{2}-1\frac{2}{3}$ (to supply 80 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell per time
Highly Fertile Soils	3 cwt Sulphate of ammonia
	2 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	$1:1:1\frac{1}{2}-1\frac{2}{3}$ (to supply 60 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell per time

Cabbage and Savoy (Summer and Autumn)

These crops have to be grown rapidly to be successful and generous manuring is required, farmyard manure being desirable on poor soils. A nitrogenous top dressing is usually required. The very early specialist crops of 'Primo' type require rich soil conditions, and dressings of hoof-and-horn or other forms of organic nitrogen are often given.

Moderately Fertile Soils	15 tons Farmyard manure
	4 cwt Sulphate of ammonia
	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	$1:1:1\frac{1}{2}-1\frac{2}{3}$ (to supply 80 parts N)
Top dressing:	2–3 cwt Nitro-Chalk or Nitra-Shell.

* "Parts per acre" is obtained by multiplying percentage nutrient in the "straight" fertilizer (sulphate of ammonia, 20 per cent N in round figures) by cwt per acre (3 cwt per acre): $20 \times 3 = 60$ "parts" N per acre.

Highly Fertile Soils	3 cwt Sulphate of ammonia 2 cwt Superphosphate 2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)
EARLIEST PRIMO CROP	
Highly Fertile Soils	5 cwt Hoof-and-horn 2 cwt Superphosphate 1 cwt Muriate of potash

Cabbage and Savoy (Winter)

Fertilizer dressings at planting time are similar to those for summer cabbage, but top dressings are not recommended as they are likely to produce too soft growth to stand hard winter conditions.

Moderately Fertile Soils	4 cwt Sulphate of ammonia 3 cwt Superphosphate 2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 80 parts N)
Highly Fertile Soils	3 cwt Sulphate of ammonia 2 cwt Superphosphate 2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)

Cabbage, Spring

Excess nitrogen in the autumn usually results in soft growth and failure to stand the winter, especially if cold weather comes suddenly after a mild late autumn. Adequate potash is needed to promote winter hardiness. One or more top dressings of nitrogen are required, commencing as soon as soil conditions permit in late winter.

When spring greens (Collards) are grown in mild coastal districts for very early cutting before the onset of hard winter weather, extra nitrogen (2–4 cwt sulphate of ammonia) may be given at planting time to increase the early yield. Sometimes organic forms of nitrogen are used in these areas. For later crops a top dressing of 4 cwt "Nitro-Chalk" per acre should be applied in early spring. The risk of winter damage from very cold weather is serious, and if there is any question of insufficiency of potash 2 cwt muriate of potash per acre should be broadcast and worked in before sowing.

Where spring cabbage or greens follow a heavily manured crop such as early potatoes little or no fertilizer may be given at planting time.

Moderately Fertile Soils	1–2 cwt Sulphate of ammonia 3 cwt Superphosphate 2–3 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 20–40 parts N) *plus* 1 cwt Muriate of potash
Top dressings: (1 or 2)	4 cwt Nitro-Chalk or Nitra-Shell (at a time)
Highly Fertile Soils	1–2 cwt Sulphate of ammonia 2 cwt Superphosphate 1 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 20–40 parts N)
Top dressings: (1 or 2)	4 cwt Nitro-Chalk or Nitra-Shell (at a time)

Cauliflower, Summer

This crop requires a high level of nutrition and should be grown on land in good heart and with a satisfactory moisture supply. If plants are at all

checked from lack of nutrients or moisture they tend to button, i.e., produce small unsaleable curds. A generous dressing of well-rotted farmyard manure helps to prevent this from happening through its beneficial effects on the moisture-retaining properties and plant nutrient-content of the soil. One or more top dressings of nitrogen are usually given, depending on the length of the growing season. Cauliflowers are intolerant of acid soil conditions (see whiptail of cauliflowers, page 28) and should be grown on soils with pH of 6·5 or above. Deficiencies of magnesium (page 25) and boron (page 27) can be serious problems under special circumstances.

As this crop is rarely satisfactory on other than highly fertile soils recommendations are only given for these conditions.

Highly Fertile Soils	30 tons Farmyard manure (well rotted)
	3–4 cwt Sulphate of ammonia
	2 cwt Superphosphate
	1 cwt Muriate of potash
Top dressings: (1 or 2)	3 cwt Nitro-Chalk or Nitra-Shell (at a time)
Compound fertilizer:	1⅓–1½:1:1 (to supply 60–80 parts N)

Cauliflower, Winter (Broccoli)

The crop usually follows early potatoes, and needs little manuring if the previous crop has been well done. Badly drained soils must be avoided, as the plants may be severely affected by wetness during the winter. Too soft growth and leaf drop leads to failure to stand the winter, especially if hard weather suddenly follows a mild late autumn. Nitrogen must therefore be balanced with adequate potash to produce hard well-balanced growth resistant to winter injury. Nitrogenous top dressings are sometimes given in early spring for the later-heading crops. Whiptail, and magnesium and boron deficiencies also occur with winter cauliflowers.

Moderately Fertile Soils	10–20 tons Farmyard manure
	2 cwt Sulphate of ammonia
	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 40 parts N)
Highly Fertile Soils	2 cwt Sulphate of ammonia
	2 cwt Superphosphate
	2 cwt Muriate of potash
	No commonly made compound fertilizer is available; one such as 1–1½:1:3 (to supply 40 parts N) would be suitable.

Beans and Peas*

Beans, Broad

Broad beans can be grown under a wide range of soil conditions and the crop is often successful on soils of medium fertility, that are not quite good enough for most market-garden crops. A soil rich in nitrogen should be avoided especially for autumn sown crops, which may be severely injured during the winter if growth is soft. Unless the soil is very poor, only phosphate and potash are required for this crop, as like other leguminous crops the root nodules of the bean have the power of utilizing nitrogen from the air.

Moderately Fertile Soils	3 cwt Superphosphate
	1–2 cwt Muriate of potash
Compound fertilizer:	0:1:2 (to supply 90 parts K_2O)

* For information on fertilizer placement for these crops see page 56.

Beans, Runner and French

Deep warm soils are required for the earliest sowings and a steady moisture supply is needed during the growing season, especially for runner beans. For this reason soils for runner beans should have an adequate humus content, farmyard manure often being given. Although the crop may respond to nitrogen in poor soils, too much nitrogen may be harmful. Light nitrogenous top dressings are sometimes given. French beans are very subject to manganese deficiency (page 27) on organic soils with high lime content.

Moderately Fertile Soils	10–30 tons Farmyard manure
	3 cwt Superphosphate
	1–2 cwt Muriate of potash
Compound fertilizer:	0:1:2 (to supply 90 parts K_2O)
Highly Fertile Soils	Farmyard manure only

Peas, Green

Peas will grow satisfactorily on soils of moderate fertility, except those subject to prolonged summer drought, and provided they are not sown when the soil is dry. A dressing of farmyard manure is useful on poor land. It is not usually necessary to apply any nitrogenous fertilizer, except for the earliest sowings when the soil is cold and the root nodule bacteria inactive, or on very poor land where 1–2 cwt "Nitro-Chalk" per acre may be given with advantage. Some growers believe that the presence of a little nitrogen in a compound fertilizer improves the colour of the peas at picking time. Peas have not proved very responsive to phosphatic manuring but they respond well to potash when the soil reserves are low. Like French beans, peas are subject to manganese deficiency which gives rise to a characteristic browning of the seed leaves inside the seed, known as "marsh spot" (pages 27–28); in acute cases yellowing of the foliage occurs.

Moderately Fertile Soils	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	0:1:2 (to supply 120 parts K_2O)
Highly Fertile Soils	No manure

Leeks and Onions

Leeks

Deep alluvial and other highly fertile soils with good moisture supply are best suited to this crop. Generous all round manuring is required and farmyard manure is usually given. Farmyard manure should be given the previous autumn or, if in the spring, it should be short and well rotted. Leeks are sensitive to soil acidity and will not grow on acid soils. Very acid soils should be limed at least 1 or 2 years before cropping with leeks. A nitrogenous top dressing may be given when the plants are established, but contact with the leaves must be avoided, otherwise the plants will be damaged.

Moderately Fertile Soils	20–30 tons Farmyard manure (well rotted)
	1–2 cwt Sulphate of ammonia
	2 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 20–40 parts N)
Top dressing:	2–3 cwt Nitro-Chalk or Nitra-Shell
Highly Fertile Soils	20–30 tons Farmyard manure (well rotted)

Onion, Bulb

Good growing conditions are required for heavy crops of bulb onions.

Onions are sensitive to soil acidity and should not be grown on acid soils; liming a year or two in advance is advisable. Although generous manuring is necessary for this crop, and well-rotted manure should be given, an excess of nitrogen may be harmful particularly in the later stages of growth. An early nitrogenous top dressing (up till the time the plants are 3–4 in. high) is often given, but dressings should not be given later than mid-May, otherwise late growth is prolonged and results in poor ripening and "bull-necked" onions.

Moderately Fertile Soils	10–20 tons Farmyard manure (well rotted)
	1–2 cwt Sulphate of ammonia
	3 cwt Superphosphate
	1–2 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 40 parts N)
Highly Fertile Soils	10–20 tons Farmyard manure (well rotted)
	1 cwt Sulphate of ammonia
	1 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 20 parts N)

Onion, Salad

This crop is subject to winter injury and nitrogen is seldom applied in the autumn. Potash is particularly important for winter hardiness. Nitrogenous top dressings may be required in early spring. When the crop is sown in spring or summer, nitrogen is given at the time of sowing.

Over Winter Crops:	
Moderately Fertile Soils	3 cwt Superphosphate
	2 cwt Muriate of potash
Top dressing:	2 cwt Nitro-Chalk or Nitra-Shell
Compound fertilizer:	0:1:2 (to supply 120 parts K_2O)
Highly Fertile Soils	No manure
Summer and Autumn Crops:	
Moderately Fertile Soils	2 cwt Sulphate of ammonia
	3 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 40 parts N)
Highly Fertile Soils	2 cwt Sulphate of ammonia

Root Crops and Potatoes

Beetroot

Beetroot may be grown on a wide range of soils but shallow soils (which tend to produce "fanged" roots) are unsuitable. Other causes of "fanging" are soil acidity and recent dressings of dung. The stand of plants may be severely damaged, especially in the seedling stage, by soil wetness even if only temporary, which leads to surface compaction and poor soil aeration. It is usually not desirable to give dung, but fertile conditions are necessary especially for the quick growth required from crops grown for early bunching. Nitrogenous top dressings are occasionally given. Beetroot is subject to boron (page 27) and manganese (page 27) deficiencies on certain soils, although the latter is much more common in round beet than in long beet.

Moderately Fertile Soils	2–3 cwt Sulphate of ammonia
	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 40 parts N)

Highly Fertile Soils	1–2 cwt Sulphate of ammonia
	1 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 20 parts N)

Carrot

Main Crop. Maincrop carrots may be grown on a wide range of soils provided they are not too shallow or heavy, but they will not grow satisfactorily on acid soils. Shallow soils and soils which have recently been dunged may produce "fanged" roots. Excess nitrogen increases the risk of splitting; otherwise, they have no special manurial requirements except that potash is likely to be important on the light sandy carrot lands, and some of these soils contain insufficient magnesium and may require 2–3 cwt Epsom salts in addition to the normal base fertilizers.

Main Crop on Fen Peats. Carrots are mostly grown on the deep light- to medium-textured peats where they make the best quality as regards shape and appearance. The "skirt" soils and heavy peats are much less suitable and are little used for carrot growing. When carrots follow potatoes or other heavily manured crop, no manuring should be necessary and this is common practice. In other instances a compound fertilizer low in nitrogen and high in potash should be used. The potato fertilizers in use on the peats are probably too high in nitrogen.

Early Bunching Crop. Deep light soils in highly fertile condition are required for the earliest bunching crops, and under intensive conditions they are often given dressings of hoof-and-horn or other organic forms of nitrogen.

MAIN CROP:		
Light Sandy Soils		2–4 cwt Sulphate of ammonia
		3–4 cwt Superphosphate
		2–3 cwt Muriate of potash
Compound fertilizer:		1:1:1½–1⅔ (to supply 40–80 parts N)
MAIN CROP:		
Fen Peat Soils		2 cwt Sulphate of ammonia
		2 cwt Superphosphate
		2 cwt Muriate of potash
Compound fertilizer:		1–1½:1:3 (to supply 40 parts N)
EARLY BUNCHING CROP:		
Highly Fertile Soils		4 cwt Hoof-and-horn
(intensive)	(*or*	3 cwt Sulphate of ammonia)
		2 cwt Superphosphate
		1 cwt Muriate of potash
Compound fertilizer:		1:1:1 (to supply 60 parts N)

Parsnip

Provided there is a sufficient depth of soil, most soils may be used for growing parsnips. Manuring is similar to that recommended for beetroot (see page 66) but over-manuring should be avoided. The crop is often grown without fertilizers on soils which have been well done for a previous crop. "Fanging" (see Beetroot) and manganese deficiency (page 27) can cause losses.

For manuring recommendations, see Beetroot (page 66).

Potato, Early

This crop requires a warm, early, easily worked soil. A plentiful supply of

organic matter is desirable and this may be supplied either as farmyard manure or by the ploughing-in of green crops such as Italian ryegrass. Farmyard manure is best applied in the autumn. To produce maximum yields at the earliest possible date, a good supply of nitrogen is required but less potash than for maincrop potatoes. The earlier the planting the greater the amount of nitrogen that should be given. In trials in the Scilly Isles in 1950 and 1951, increasing the amounts of "Nitro-Chalk" up to 12 cwt per acre gave increases in yield which were profitable at the prices realized at that time. Fertilizers are best broadcast over the ridges prior to planting, which, when the ridges are split back, results in mixing of the fertilizer with the soil especially near the tubers (see also Fertilizer Placement on page 56).

Moderately Fertile Soils	10–20 tons Farmyard manure 6 cwt Sulphate of ammonia 5 cwt Superphosphate 2 cwt Muriate of potash
Highly Fertile Soils	Apply fertilizers as for moderately fertile soils, but without farmyard manure.
Compound fertilizer:	1:1:1 (to supply 120 parts N)

Swede

A good moisture supply is required for swedes and the crop is grown most successfully in the cooler parts of the country. Swedes are responsive to phosphatic manuring, but excess of nitrogen may be harmful by impairing the keeping quality of the roots. Boron deficiency (page 27) gives rise to a condition known as "brown heart", in which the roots are fibrous and inedible.

Moderately Fertile Soils	1 cwt Sulphate of ammonia 4 cwt Superphosphate 1 cwt Muriate of potash
Compound fertilizer:	1:4:4 (to supply 20 parts N)

Turnip

Rapid growth is required in order to produce good quality roots. Early warm soils and high fertility conditions are necessary for early sowings of "bunching" crops. A good supply of humus in the soil is helpful in retaining moisture and promoting rapid growth, and rather heavier dressings of nitrogen should be given to turnips than to swedes.

MAIN CROP:	
Moderately Fertile Soils	10 tons Farmyard manure 2 cwt Sulphate of ammonia 3 cwt Superphosphate 1 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 40 parts N)
Highly Fertile Soils	2 cwt Sulphate of ammonia 3 cwt Superphosphate 1 cwt Muriate of potash
Compound fertilizer:	1:2–2½:2–2½ (to supply 40 parts N)
EARLY BUNCHING CROP:	
Highly Fertile Soils (intensive)	3 cwt Sulphate of ammonia 3 cwt Superphosphate 1 cwt Muriate of potash
Compound fertilizer:	1:1:1 (to supply 60 parts N)

SALAD CROPS

Celery, Self-blanching

Self-blanching celery can only be grown successfully under conditions of

high fertility and good moisture supply, preferably as an irrigated crop. The crop has a high requirement for nitrogen and one or more top dressings are usually necessary.

Highly Fertile Soils	30 tons Farmyard manure
	2 cwt Sulphate of ammonia
	1 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1–1½:1:3 (to supply 40 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell
Fen Peat Soils	See under "Winter Celery"

Celery, Winter

This crop is grown most successfully on alluvial soils and deep peats. Generous manuring is practised but excess of nitrogen is to be avoided because of the danger of producing pithy stalks and susceptibility to winter injury. Top dressings of a nitrogenous fertilizer are sometimes required. Boron deficiency (page 27) gives rise to a condition known as "cracked stem".

Fen Peat Soils. Celery is grown on the deep light peats, loamy peats and peaty loams. Farmyard manure if needed should be ploughed-in in the autumn. Experiments have shown that nitrogen reduces yield, and placement of fertilizers may cause root injury in some seasons. Superphosphate, muriate of potash and common salt broadcast before planting, have all increased yields: salt should be broadcast at least one month before planting.

Moderately Fertile Soils	25 tons Farmyard manure
	3 cwt Sulphate of ammonia
	4 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)
Highly Fertile Soils	3 cwt Sulphate of ammonia
	2 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)
Light Fen Peat Soils	10–20 tons Farmyard manure
	5 cwt Superphosphate
	5 cwt Muriate of potash
	5 cwt Agricultural salt (*after ploughing*)
Compound fertilizer:	0:1:2 (to supply 300 parts K_2O)

Lettuce, Summer

Summer lettuce may be grown on most soils provided they are not acid or very dry. Lettuce is very susceptible to acidity, particularly in the seedling stage. Cos lettuce requires conditions of higher fertility than cabbage types. If farmyard manure is given it should be well rotted and worked into the soil well in advance of the crop, since organic matter on the surface of the soil increases the risk of *Botrytis* attack. Manganese deficiency (page 27) may be a problem on organic or wet soils with high lime content; since lettuce is sensitive to spray damage with manganese sulphate, only 2½ lb per 100 gal should be used. Magnesium deficiency (page 25) may occur on the lighter soils particularly if excessive dressings of potash have been applied.

Moderately Fertile Soils		4–6 cwt Hoof-and-horn
	(*or*	4 cwt Sulphate of ammonia)
		4 cwt Superphosphate
		2 cwt Muriate of potash
Compound fertilizer:		$1:1:1\frac{1}{2}$ (to supply 80 parts N)
	or	$0:1:2$ (to supply 120 parts K_2O)
		plus hoof-and-horn
Highly Fertile Soils		2 cwt Sulphate of ammonia
		2 cwt Superphosphate
		1 cwt Muriate of potash
Compound fertilizer:		$1:1:1\frac{1}{2}$–$1\frac{2}{3}$ (to supply 40 parts N)

Lettuce, Winter

Well drained soils are required for this crop. In addition the crop suffers during the winter if the soil runs together or "caps" badly on the surface. It is usual to give phosphates and potash only at the time of sowing, the latter being particularly important so far as winter hardiness is concerned. When the plants are beginning to grow in spring, it is necessary to give a top dressing of "Nitro-Chalk" or other quick-acting nitrogenous fertilizer.

Moderately Fertile Soils	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	$0:1:2$ (to supply 120 parts K_2O)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell
Highly Fertile Soils	No base manuring
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell

Radish

If radishes are to be of good quality they must grow quickly, and satisfactory moisture supply and high fertility conditions are essential. Light warm soils are necessary for the earliest crops. Manuring should be generous, especially as regards nitrogen, and it is common to give hoof-and-horn or some other organic nitrogenous fertilizer in sufficient amounts for several successive crops.

Highly Fertile Soils (Manuring for several successive crops)

	10 cwt Hoof-and-horn
	2 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	$0:1:2$ (to supply 40 parts P_2O_5)
	plus hoof-and-horn

Tomato, Outdoor

Soils with an adequate but not excessive moisture supply are required for steady growth and good quality fruit. A dressing of well rotted farmyard manure or compost before planting helps to achieve this and reduces splitting of the fruit. The top dressing should be given when the fruit begins to swell.

Moderately Fertile Soils	15 tons Farmyard manure
	2 cwt Sulphate of ammonia
	3 cwt Superphosphate
	3 cwt Muriate of potash
Compound fertilizer:	$1:1:1\frac{1}{2}$–$1\frac{2}{3}$ (to supply 50 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell
Highly Fertile Soils	15 tons Farmyard manure
	2 cwt Sulphate of ammonia
	1 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	$1:1:1\frac{1}{2}$–$1\frac{2}{3}$ (to supply 40 parts N)
Top dressing: (if needed)	3 cwt Nitro-Chalk or Nitra-Shell

Other Crops

Marrow

A good supply of moisture is necessary for this crop, and a substantial dressing of farmyard manure is usually given mainly for its moisture-retaining properties. Nitrogenous top dressings are sometimes necessary.

Moderately Fertile Soils	20 tons Farmyard manure
	3 cwt Sulphate of ammonia
	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell
Highly Fertile Soils	20 tons Farmyard manure
	2 cwt Sulphate of ammonia
	2 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 40 parts N)
Top dressing: (if needed)	3 cwt Nitro-Chalk or Nitra-Shell

Spinach, Summer

Unless this crop grows on rich soils it fails to make enough leaf and bolts early. A nitrogenous top dressing is often needed for early crops. Spinach is extremely sensitive to acidity, and lime if required should be applied 2 or 3 years in advance of cropping.

Highly Fertile Soils	2 cwt Sulphate of ammonia
	2 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 40 parts N)
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell

Spinach, Winter

As with many winter crops it is usual to give phosphates and potash only in the autumn and follow up with nitrogenous top dressings in early spring.

Moderately Fertile Soils	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	0:1:2 (to supply 120 parts K_2O)
Highly Fertile Soils	No base manure
Top dressing:	3 cwt Nitro-Chalk or Nitra-Shell

Sweet Corn

A deep, well-drained soil and a good supply of moisture are needed. Nitrogen is important. If phosphate is low, growth is poor, but this is unlikely to happen on fertile market-garden soils. Bulky organic manure is rarely needed, unless the land has not received organic manure for some years.

Moderately Fertile Soils	4 cwt Sulphate of ammonia
	3 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1⅓–1½:1:1 (to supply 80 parts N)
Highly Fertile Soils	3 cwt Sulphate of ammonia
	2 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	1⅓–1½:1:1 (to supply 60 parts N)

Perennial Crops

Asparagus

Asparagus will grow satisfactorily on a wide range of soils provided the drainage is adequate. Good soil structure is of importance in the production of straight shoots. Dressings of bulky organic manures help to maintain the soil in an open, friable condition and to achieve this 30–40 tons of farmyard manure per acre should be ploughed in before planting. If available, similar dressings of farmyard manure should be given every third or fourth year, worked in between the rows in the autumn. Asparagus is sensitive to acidity and lime should be applied when necessary. Common salt is widely believed to be necessary, but benefit from its use has not been proved; in view of the damage salt may often cause to soil structure its use is not recommended. On some of the sandy soils on which asparagus is being grown, fertility is inherently low, and much more nitrogen and potash may be needed at the outset than is recommended below. The fertilizer dressing may be applied between the ridges after earthing up.

Before Planting	3 cwt Superphosphate
	1 cwt Muriate of potash
Compound fertilizer:	0:1:1 (to supply 60 parts K_2O)
Top dressing (first year)	2 cwt Nitro-Chalk or Nitra-Shell when growth commences in the first spring only
Subsequent Years	3–4 cwt Sulphate of ammonia
(In early spring)	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60–80 parts N)

Rhubarb

Rhubard should be grown on soils of adequate depth and good moisture supply. Irrigation may be required in dry districts. The crop is an exhausting one and a high level of fertility is required. Rhubarb is unsatisfactory on acid soils and lime should be applied where needed.

Forcing Rhubarb. In the original preparation of the land before planting, farmyard manure should be given at 40 tons per acre. Provided that the land is in good heart nothing further should be required until the year in which the roots are lifted for forcing. "Nitro-Chalk" or sulphate of ammonia should be given at 5 cwt per acre just before growth commences in spring.

Field Rhubarb. When preparing the land before planting, farmyard manure should be applied at 40 tons per acre and further dressings of manure or straw are given as winter mulches during the life of the crop. No other manure or fertilizer is given until pulling commences (generally in the third year after planting), when fertilizers should be applied just before mulching. If mulching is not practised, the fertilizer dressing should be given in late winter before growth starts. A top dressing of "Nitro-Chalk" is given between pullings, and after the final pulling provided the land is clean.

	3 cwt Sulphate of ammonia
	3 cwt Superphosphate
	2 cwt Muriate of potash
Compound fertilizer:	1:1:1½–1⅔ (to supply 60 parts N)
Top dressings: (1 or more)	4 cwt Nitro-Chalk or Nitra-Shell at a time

Manuring Gardens and Allotments

THE manuring of vegetable crops in gardens and allotments follows similar lines to those given for commercial crops in earlier sections of the bulletin. In a small garden it would, however, be impracticable to give the individual attention to the manuring of the separate crops as described earlier for commercial crops. A brief outline of the more important sections, together with simplified manurial programmes, is therefore given in the following pages for the general guidance of allotment holders and other gardeners.

The points of principal importance are the maintenance of organic matter supply, the use of lime, and the use of fertilizers. When translating manurial recommendations for commercial crops into garden practice, it is useful to remember that 2 cwt per acre is equivalent to ¾ oz per sq. yd; conversely, 2 oz per sq. yd of any given fertilizer is roughly equivalent to 5 cwt per acre.

Remember also how important it is to keep manures and fertilizers under proper conditions. Do not leave stable manure exposed in the open, but if you cannot spread it on the ground for use straightaway, protect it from rain and from drying out.

Fertilizers should be stored in a dry place. Keep the bags off the ground by means of bricks or boards. They must not come in contact with metals especially tools and implements which will soon be ruined by chemical corrosion. Keep lime apart from fertilizers and see that all bags and other containers are clearly labelled, particularly if weed-killers, insecticides and fungicides are also being stored in the same shed.

MAINTENANCE OF ORGANIC MATTER

For a number of reasons a good supply of organic matter in the soil is necessary for the satisfactory growth of garden crops. Firstly organic matter acts as a reservoir for moisture and helps to tide plants over periods of drought. Secondly, organic matter binds the soil particles together into crumbs and so makes it easier to obtain a satisfactory tilth for the sowing of small seeds. Such a tilth is relatively stable and not easily broken down by heavy rain or cultivations, thereby preventing "capping" of the surface. Thirdly, soil organic matter acts as a storehouse of slowly available nitrogen.

Farmyard Manure

Farmyard or stable manure is, of course, the traditional form in which organic matter is added to garden soils. It is variable in composition depending on such factors as the kind, age and feeding of the animal producing the manure, the ratio of straw to droppings, the conditions and length of storage. Farmyard manure also supplies plant nutrients, such as nitrogen, phosphate and potash, much of which may be lost if manure is allowed to stand in heaps exposed to the rain.

Wherever practicable manure should be spread and dug straight into the ground as soon as it is received. Long manure (i.e., manure with much undecomposed straw in it) is particularly useful on clayey soils if applied in

the autumn. It should not be applied in spring as this tends to dry out the ground.

In view of the scarcity of farmyard or stable manure, it is important to incorporate it in the top spit, where it will be of most benefit to seedlings and the growing crop. The old practice of digging manure in deeply is a relic of the time when supplies were abundant and gardeners could afford to use manure for "making" garden soil two and more spits deep. Nowadays there is rarely more than enough manure for the immediate needs of those crops which specially benefit from it, and the best place for the manure is within easy reach of the growing plant. The same rule applies to well-made compost.

Compost

The present shortage and high cost of farmyard manure has caused many gardeners to look elsewhere for a source of organic matter and, in practice, composted vegetable refuse has proved to be a useful substitute. Most garden refuse can be composted satisfactorily, although it is often simpler to burn the hard stems of cabbages and related plants. Diseased materials, e.g., the roots of cabbage plants infected with club root, should be burnt rather than composted, as should the roots of certain perennial weeds (bindweed, couch grass, creeping thistle, etc.) which may otherwise grow in the compost heap.

A compost heap should be built in a sheltered position away from drying winds, and when only small quantities of vegetable refuse are available, a pit or container (such as can be knocked together from sheets of corrugated iron) is very useful.

The heap should be built in layers, first a layer of vegetable refuse 6–9 in. thick (dry material should be watered) and then if possible a layer of animal manure about 2 in. thick. If manure is not available sulphate of ammonia, "Nitra-Shell' or "Nitro-Chalk" should be added, say one handful to 1–2 sq. yd of heap 9 in. thick. If sulphate of ammonia is used, a sprinkling of lime, such as hydrated lime, ground limestone or chalk, should be given to every other layer of rubbish — say a couple of large handfuls per square yard of heap. Direct contact between the lime and fertilizer or manure should be avoided, otherwise useful nutrients will be lost; therefore, add the sulphate of ammonia to one layer of the heap, and the lime to the next and so on. If "Nitro-Chalk" is used, lime is unnecessary.

If waste straw is available, this may be composted in a similar way with animal manure, sulphate of ammonia and lime, "Nitra-Shell' or "Nitro-Chalk". It is essential to wet each layer of straw thoroughly as it is added to the heap.

Properly made compost heaps generate heat, which declines a few weeks after building. If it is desired to speed up the composting process the heap should then be turned. Water should be given at this time if the heap is at all dry. The heat destroys weed seeds, but only very large heaps become hot enough to destroy most of the weed seeds.

Fuller details on composting may be found in Growmore Leaflet No. 37.*

Other Organic Manures

Gardeners can often obtain other organic manures locally. Spent mushroom

* Growmore Leaflet No. 37: *How to make Compost Manure from Garden Refuse*, obtainable free and post free on application to the Ministry of Agriculture (Publications), Ruskin Avenue, Kew, Surrey.

manure is an example, and the advantages and disadvantages of this material are discussed on page 21. Poultry and rabbit manures are also valuable and are particularly useful as animal manure for compost making.

Sometimes, "green manuring" can be practised as a means of adding organic matter, since it also protects the soil surface and prevents loss of nutrients. When land is vacant for several months (e.g., after early potatoes) it may be possible to sow ryegrass (say, 1 oz seed to 10 sq. yd) for digging in during the autumn or winter. Sulphate of ammonia, "Nitra-Shell' or "Nitro-Chalk" at 1–2 oz per sq. yd raked in before sowing will help to encourage vigorous growth of the green manure crop.

In large gardens and vacant allotment plots, considerable benefit can be obtained by sowing portions of the ground down to grass and clover for a period of 1–3 years. It may also be advantageous to include grass in a 3–4 year rotation with vegetable crops. The grass should be kept grazed with small livestock or cut two or three times during the summer, the mowings being left on the ground to rot.

Crops Requiring Organic Manures

When the amount of farmyard manure, compost, etc., is limited, supplies should be reserved for such crops as cauliflowers, celery, leeks and soft fruits, especially strawberries and black currants, and, if there is sufficient, for potatoes. Farmyard manure and compost are best dug in during the winter, and they should not be applied before planting in the spring unless they are well decomposed. As is well known, freshly applied farmyard manure may cause "fanging" in root crops such as carrots and parsnips.

USE OF LIME

Lime is essential to plants, and when soils are short of it many garden crops are unsatisfactory, and in extreme cases they may fail completely.

Nevertheless, some gardeners go to the other extreme and give excessive dressings of lime, often over a long period. This should be avoided, since an excess of lime in some soils is liable to produce a number of deficiency disorders in susceptible crops. Examples of this are boron deficiency in celery ("cracked stem") and manganese deficiency in round beet ("speckled yellows"). The soils that are especially liable to produce such troubles if overlimed, are marshy and peaty soils and light sandy soils (see also page 27).

Attempts to improve the tilth of soils, other than acid clays, by liming are misdirected; for instance the tilth of compact heavy silts (sometimes mistaken for clays by beginners) cannot be improved by liming.

Lime is a useful deterrent of club root of cabbages, but, on the other hand, an excess of lime may encourage common scab in potatoes on soils liable to produce that disease.

The most useful forms of lime for gardeners are hydrated lime, ground limestone and chalk. So far as neutralizing soil acidity is concerned 1 lb of hydrated lime is roughly equivalent to 1½ lb of ground limestone or chalk. Lime is best applied after digging, although if it is necessary to give a heavy dressing, part may be dug in and part worked into the surface soil afterwards.

Once the lime content of the soil has been built up to a satisfactory level, it is only necessary to give occasional light dressings. The rate of loss of lime varies according to soil and manuring, but as a guide 8–12 oz per sq. yd

of hydrated lime, ground limestone or chalk every few years should be an adequate maintenance dressing. This does not, of course, apply to chalky soils and other soils naturally containing free lime, which require no additional lime.

Local Education Authorities are sometimes in a position to give advice to gardeners and allotment holders who want to know whether lime is needed and, if so, in what quantities. Advice should be sought, preferably through an allotment or horticultural society, from the Director of Education or Horticultural Adviser. For further information on liming, see Growmore Leaflet No. 111: *The Use of Lime in Horticulture.**

THE MAIN FERTILIZERS AND THEIR USES

Nitrogen, phosphates and potash are the principal nutrients required by plants. They are usually supplied in the form of fertilizers, although organic manures such as farmyard manure also contain small amounts of these and other nutrients. For an account of the part played by these nutrients in the life of the crop, see page 22 onwards.

Nitrogen

Nitrogen may be applied to the soil in organic and inorganic forms, and both have their uses in garden practice. The best known organic forms are hoof-and-horn and dried blood (both usually contain about 13 per cent of nitrogen). The most widely used inorganic forms are sulphate of ammonia (20–21 per cent nitrogen), "Nitra-Shell" (20·5 and 23 per cent nitrogen) and "Nitro-Chalk" (15·5 and 21 per cent nitrogen).

Hoof-and-horn and dried blood are relatively expensive and often used for high quality crops. Hoof-and-horn is rather slower in action than the inorganic fertilizers, and for this reason it is sometimes used for long-standing crops, such as broccoli, where a supply of nitrogen is required over a long period. It is equally useful for lettuce, celery, summer cauliflower and out-door tomatoes, for which a steady supply of nitrogen throughout growth makes for better quality produce.

Sulphate of ammonia, "Nitra-Shell' and "Nitro-Chalk" are relatively cheap and satisfactory for most purposes. Sulphate of ammonia makes the soil slightly acid, whereas the other two add a small quantity of lime to the soil. The acidifying action of sulphate of ammonia is, of course, an advantage on soils which contain an excess of lime.

When a crop needs a large supply of nitrogen, it is sometimes better to give part of the nitrogen dressing at sowing or planting, and to keep some for top dressing later (e.g., with early brassica crops). Otherwise, the large amount of soluble nitrogen added to the soil may cause excessive growth at he outset, and some nitrogen may also be lost from the soil in wet periods.

Phosphates

Superphosphate (18 per cent water-soluble phosphoric acid), bonemeal (22 per cent insoluble phosphoric acid, 2–5 per cent nitrogen), and steamed bone flour (28 per cent insoluble phosphoric acid, 1 per cent nitrogen) are

* Obtainable free and post free only from the Ministry of Agriculture (Publications), Ruskin Avenue, Kew, Surrey.

the most widely used phosphatic fertilizers in gardens. The phosphate in superphosphate is soluble in water and therefore much more readily available to plants than the phosphate in bonemeal and steamed bone flour. Phosphates are most needed in the seedling and early stages of growth; hence it is important to work them into the seedbed during the final preparation before sowing, so that they are readily accessible to the germinating seedlings. In this respect, the advantage of the immediate effect obtainable by using superphosphate will be appreciated.

Potash

Muriate of potash (50–60 per cent potash) and sulphate of potash (48 per cent potash) are generally used in gardens. Muriate of potash is satisfactory for most crops. Sulphate of potash may be preferable for potatoes and this fertilizer should be applied to land which is likely to be used for soft fruit crops. Bonfire ashes contain a small percentage of potash. They should be spread on the land before they are made wet by rain. For fuller particulars of these and other fertilizers, see pages 31–44.

General Use of Fertilizers

When arable or grassland is converted into a garden, the level of "available" phosphate and potash is often too low for intensive cropping. Under such conditions it is often a wise plan to give 2 oz per sq. yd each of superphosphate and sulphate of potash after the land is first dug.

After this most gardens may be manured satisfactorily along the following lines: (i) before sowing or planting, give a good general fertilizer containing nitrogen, phosphate and potash as a base dressing; (ii) where needed by the cabbage family, etc., use sulphate of ammonia, "Nitra-Shell" or "Nitro-Chalk" for top dressing.

Base Dressing

Many good general fertilizers are available; e.g., a compound fertilizer with an analysis of 7 per cent nitrogen (N), 7 per cent water-soluble phosphoric acid (P_2O_5) and 10·5 per cent potash (K_2O). Alternatively a suitable mixture could be made up as follows:

4 lb Sulphate of ammonia
4 lb Superphosphate
2 lb Muriate or sulphate of potash

The ingredients should be thoroughly mixed just before use, only enough being mixed for use fresh. When a proprietary compound fertilizer is being selected, the particulars of analysis (N, P_2O_5 and K_2O percentages) should be studied, as this is one important means of judging the value of the compound concerned (see also pages 48–52).

Such mixtures or compound fertilizers should be applied and raked in at 2 oz per sq. yd before sowing most root crops; 3 oz per sq. yd might be raked in before sowing onions; 4 oz per sq. yd before planting greenstuff, but for broccoli, which has to stand the winter, not more than 2–3 oz at planting. As a rough guide, other crops may be given 2–3 oz per sq. yd before sowing or planting, unless the land is very fertile. With potatoes, fertilizers are best scattered over the sides and bottom of the drills before planting the seed tubers, applying 3 oz per yard-run of drill. Spring cabbage grown on ground

which has been well manured for a previous crop does not usually need fertilizers at planting time, but on less fertile ground up to 2 oz per sq. yd may be given.

Base Dressings of Compound Fertilizer or Mixture

Crop	*oz per sq. yd*	
Brassicas (green)	4	
Broccoli	2–3	
Cabbage (spring)	0–2	
Onions	3	
Potatoes	3	(*per yd-row*)
Roots	2	
Other crops	2–3	

Top Dressing

Some crops (e.g., cauliflowers, spinach, spring cabbage, Brussels sprouts) benefit during the growing season from one or more nitrogenous top dressings of 1 oz per sq. yd of "Nitra-Shell", "Nitro-Chalk" or sulphate of ammonia.

Top dressings should be given during the growing season, particularly if the crop seems to be hanging back or, with Brussels sprouts, if the lowest leaves are yellowing prematurely. Spring cabbage should be top dressed (often in two half dressings) in February or March to stimulate growth. Top dressings should not be overdone, or the crop may become too soft and leafy and may fail to mature properly (e.g., Brussels sprouts). Onions should not be top dressed after the end of May, otherwise ripening and storage quality may suffer.

Care should be taken to spread the fertilizer evenly and to avoid scattering it on the leaves; plants with sheathed leaves like celery and leeks are easily damaged in this way. Having previously cleared the weeds, apply top dressings when the soil is moist and friable, and hoe in lightly.

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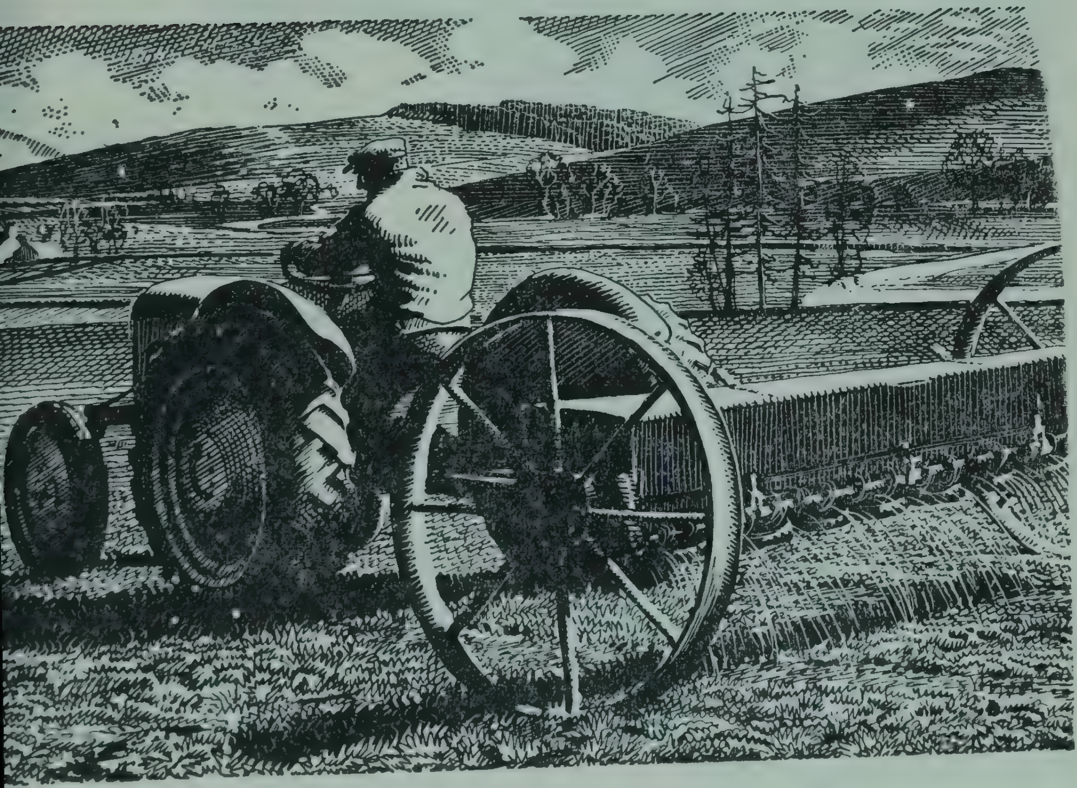

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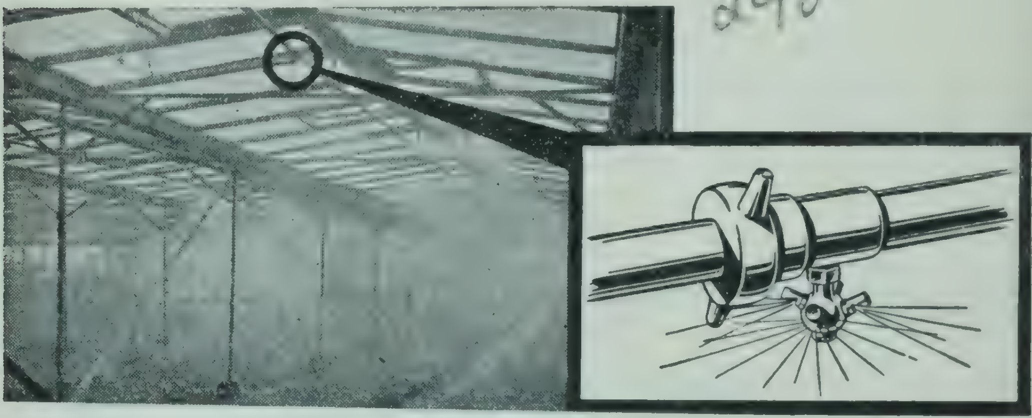
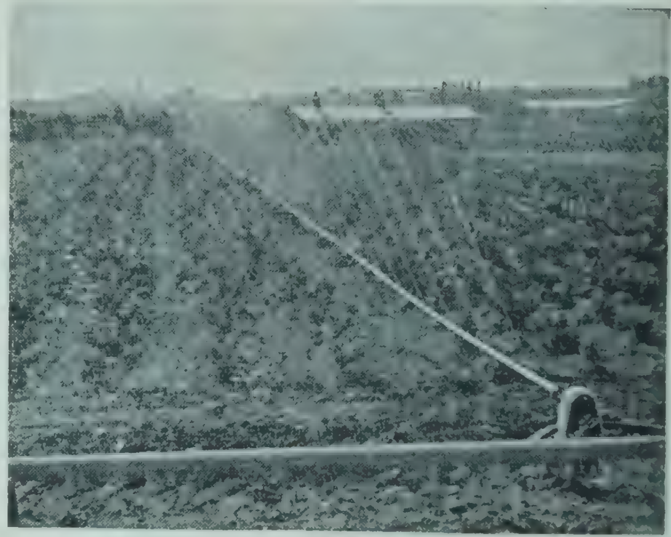


INSIDE . . . semi-permanent high level light alloy cluster head diffuser nozzle spray lines in ten 100 ft. × 10 ft. bay Dutch light structures.



OUTSIDE . . . 450 ft. × 1½" oscillating spray line with nutrient) pump and bucket—one of many famous Kinnell outdoor systems.

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